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Northampton County, Pennsylvania

by Benjamin LeRoy Miller
Donald McCoy Fraser
Ralph LeRoy Miller

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FOREWORD

This volume on Northampton County is presented in partial fulfillment of a moral obligation that the senior author has long felt. During his occupancy of the chair of geology in Lehigh University since September, 1907, he has been engaged in the study of local geologic problems and has endeavored to keep in touch with all geologic investigations carried on in eastern Pennsylvania and in the adjoining portion of New Jersey. Colleagues in the Department of Geology both of the teaching staff and student body have contributed much. Every year scores of students have been conducted on field trips to various places in the region and many have been assigned to special researches or have on their own accord made similar studies. Numerous operators in the stone industries have brought their problems to the attention of the geological staff. From all these sources a mass of information has accumulated. While many of the problems involved in these investigations have apparently been solved, the number of unsolved questions has increased rather than diminished. The studies are therefore incomplete and hence somewhat unsatisfactory. Nevertheless it seems advisable to put in permanent form a record of observations and present interpretations for the use of students of the six colleges* of the Lehigh Valley and for other persons interested in the geology of this section, either from the practical, scientific or cultural aspects.

There is no doubt in the minds of the authors that many of the conclusions presented will be modified or entirely set aside by later investigators as the result of new information or because of different points of view. Eventually the true explanations will be forthcoming.

Although it may not always appear in the text and maps, there are many points where much uncertainty exists and the statements made are considered by the authors as more or less tentative. They will welcome suggestions and criticisms. Many of the geologic formational contact lines have had to be drawn through regions covered by talus, glacial débris and residual soil and hence are likely to be in error. From time to time information obtained through drilling, excavations or perhaps through geophysical investigations will probably make it possible to correct many of the present conclusions.

At the request of the senior author, the Allentown, and the Pennsylvania portion of the Easton and Delaware Water Gap topographic maps were recently revised and constitute the base for the accompanying geologic map† The field work was practically completed before the revised maps were received and it has not been possible to revisit all places with the new maps in hand. Therefore it is probable that in some cases the transfer of geologic lines and location of various mines, quarries, wells, etc., from the old to the new base may have resulted in some error, but it is hoped that such errors may prove to be slight.

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* Muhlenberg College and Cedar Crest College in Allentown, Lehigh University, Moravian College and Theological Seminary, and Moravian College for Women in Bethlehem, and Lafayette College in Easton.

† Although the topography of the Delaware Water Gap quadrangle west of Delaware River has been remapped, the copper plates had not been engraved in 1938 and so the topography for this area on the accompanying map is not revised. Culture at Bangor, Wind Gap and Martins Creek has been brought up to date.

FOREWORD

In the study of the geology of any region there is seldom, if ever, a report prepared that can be looked upon as final, and the almost universal wish of any geologist is that he might delay publication until further data were available. On the other hand, the general recognition that progress toward ultimate truth is facilitated by the dissemination of existing information prompts scientific workers to acquaint their fellow-workers with the results of their investigations, incomplete though they may be.

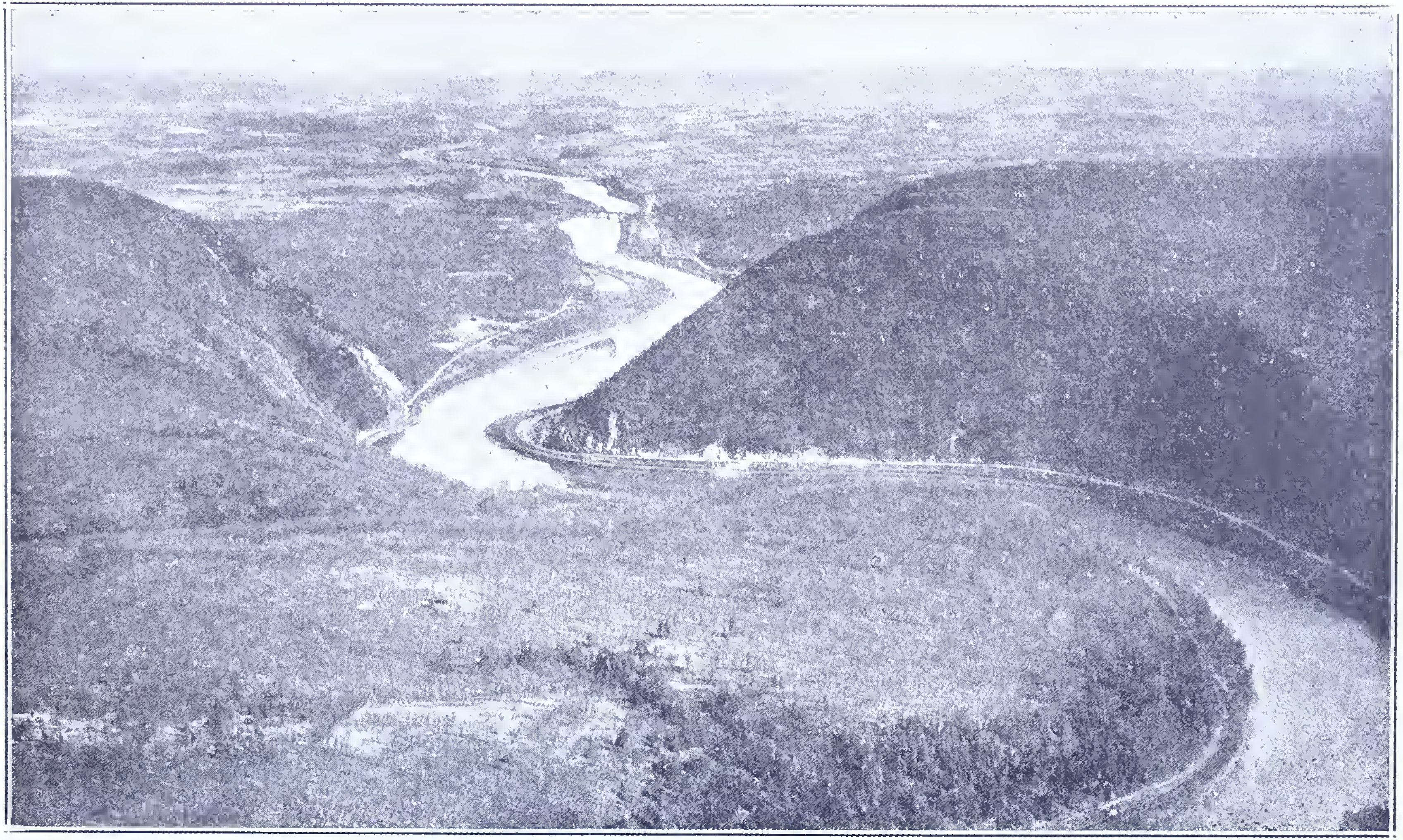
In the inauguration of this work it was intended to include only discussions of the geology and physiography of Northampton County. Gradually, however, the plan has been extended to include other geographic features. The development of scientific knowledge has called for careful examination of the literature, which has led to the preparation of an elaborate bibliography and cartography. If these be regarded as unnecessarily detailed and to include some references of minor importance, the excuse may be offered that such a presentation may be the means of saving much time for future investigators. The chapter on the derivation of the place names is the outgrowth of the cartographic studies. Finally, the discussion of the industries of the county is included because of the fact that in most cases they are intimately related to the physiographic or geologic features of the region.

To the scores of persons who have contributed information useful in the preparation of this volume, the unstinted thanks of the authors are offered. Most of these must be unnamed because of the inability to recall the exact contributions made by these individuals over a period of more than thirty years. The assistance of several however has been so material that they must be mentioned even though their specific contributions cannot be described. Among these are Dr. Edgar T. Wherry, the late Dr. Edward H. Williams, Jr., and J. Osborn Fuller, in addition to those whose contributions are included in this volume. It must also be recognized that the authors have freely drawn on the publications of previous workers in the region; in fact, these investigations are built on the foundations laid by others during the past hundred years.

With the expressed hope that this volume may be helpful to the residents of Northampton County and others in their scientific investigations or in their utilization of the natural mineral products of the region, the authors present it to the public. The prosecution of the work has been a real pleasure in every respect and the continuation of these studies is commended to those persons of similar interests. The profits of scientific research cannot be evaluated in dollars and cents, but must be measured by the enjoyment, mental stimulation and positive thrills that come with the discovery of some scientific fact or principle. If the perusal of the pages of this volume inspires some young as well as older minds and leads them to devote some of their efforts to unraveling the geological story or to the further investigation of Nature's processes, the labors of the authors will not have been in vain.

BENJAMIN L. MILLER

Lehigh University,
Bethlehem, Pennsylvania.
June, 1938.



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Aerial view of the Delaware Water Gap looking south. The Schooley Peneplane of Kittatinny (Blue) Mountain developed in the Shawangunk Formation is well exhibited with the Great Valley beyond and South Mountain on the sky line.

NORTHAMPTON COUNTY, PENNSYLVANIA

INTRODUCTION

By Benjamin L. Miller

Northampton County forms one of the eastern tier of counties bordering the Delaware River and is situated slightly south of the middle of the State. It lies between parallels 40° 32′ and 40° 58′ and meridians 75° 3′ and 75° 37′. It is irregular in shape and has an area of 372 square miles. It includes portions of the following 15′ quadrangles of the U. S. Geological Survey: Allentown, Delaware Water Gap, Easton, Mauch Chunk, Slatington and Wind Gap.

The geologic history of Northampton County, as read in the rocks themselves and the topographic forms that have been carved from these thick and varied lithologic masses, is a long and complicated one. In part it has been deciphered but in large measure the final, and hence the correct, interpretations will probably not be reached until far more information is available.

More than a billion years of history is involved in the geologic story of Northampton County. During this long period of time, the region has been in preparation for Man, the only animal that has ever possessed the ability to utilize, except in a small way, the products of Nature's factories or to bring partially under his control the dynamic forces of the Universe. The long geologic record is one of alternating periods of construction, modification and destruction. Seas, plains and mountains in turn have occupied these regions; forces so gigantic that Man's greatest efforts seem pucrile in comparison, have uplifted, depressed and folded the rocks as though they were thin pieces of paper. More than 100,000 cubic miles of water has fallen from the skies in the form of rain and snow since the last emergence from beneath oceanic waters, and the resultant streams have carried from the region such masses of rock that if all were replaced the region would contain mountains outrivaling the Himalayas.

The human history in comparison with the geologic is extremely brief. The Indians probably occupied the region a few hundred years before the white man came but he rarely interfered with or modified the forces of Nature. The white men from Europe, from their first arrival, have been altering the surface topography and in countless ways have either aided or impeded the natural forces of destruction and construction. The products that required millions of years for their formation have been used in various manufactured articles. The rocks, the soils and the ores of the region have been put to use and, in

some cases, exhausted. Igneous rocks of natural origin bear comparison with the vast heaps of solidified slag that have accumulated about the iron furnaces. The shovel, scraper and steam shovel have made great holes in the surface and have piled up mounds of débris in a manner that no natural forces can duplicate; the streams have been modified and erosion accentuated in some localities and retarded in others. Of course, the effects of Man's efforts have resulted in only minor modifications of Nature's handiwork although in our egotism we are inclined to boast of human achievements.

The first white settlers came to the region a little over 200 years ago and the increase in population has been a steady one ever since. Although the agricultural interests predominated for the first decades, the manufacturing industries were early developed and for many years have been dominant. The transportation facilities and the proximity to the metropolitan districts have given the county an industrial advantage which has been still further enhanced by the nearness of the anthracite mines. The mining and quarrying operations have contributed much to the development of the county. At one time it ranked as the most important iron ore producing section of the State. In recent years it has been foremost in the slate and cement industries.

The future of the region involves pure speculation. Man and Nature in cooperation and in opposition are continually changing the topographic features of the region. If we were safe in concluding that the agents and forces now at work will continue to operate as they do now, we might compute the time that will be required to wear down the existing hills and reduce the entire region to a monotonous plain across which lazy streams might take their winding course to the sea. The history of the region does not warrant the assumption of such a premise. We may be certain that the region will continue to change but in what manner and at what rate we do not know, and what its appearance will be when other millions of years have left their marks no one can say.

CULTURE

Use.—With the exception of the most rugged portions of Kittatinny (Blue) Mountain and the South Mountains, all of Northampton County is inhabited and the soil or underlying rocks have been utilized for the growing of crops, the mining or quarrying of useful mineral products or for the sites of structures of various kinds. The cultivated portions of the county are used for growing wheat, corn, hay, oats, barley and potatoes and for grazing. Dairying is an important industry. The location in proximity to the great commercial

communities of New York and Philadelphia on one hand and to anthracite on the other, as well as the excellent transportation facilities, have gradually developed the region more and more along industrial lines with a great variety of manufactured products originating in the numerous villages and cities. Iron and steel, machinery, coke, cement, textiles and scores of minor articles are produced in the region. The higher and rougher mountains are too rocky to be cultivated but they have furnished much timber to the residents. The best lumber even in the early settlement of the region came from the adjoining counties north of Kittatinny (Blue) Mountain but the forests of the county did supply the settlers with logs and lumber, with fuel and with charcoal for the iron furnaces. Even yet the forested portions of the county contribute to the welfare of the residents.

The more level portions of the county are most thickly settled. The rougher portions are more thinly populated but there is practically no waste land. Here and there are residences on the slopes and tops of the steep hills and mountains, some of which are occupied during the entire year and others only during the summer. Some fairly steep slopes have been cultivated by the removal of the larger rocks of the hillside talus. With the exception of Kittatinny (Blue) Mountain, which forms the northern boundary, it is probable that there is no place within the entire county that is more than half a mile from a residence. The population is naturally most dense in the limestone valleys where the principal towns are situated and where practically every foot of the area is capable of cultivation. The slate region, with steeper hills, has several small villages clustered about the slate quarries. Some of the hillsides are too steep for cultivation but furnish pasturage or are covered with trees. Kittatinny (Blue) Mountain and the gneiss hills south of the Lehigh Valley are least populated.

Population.—Population figures are an interesting study.

Population of Northampton County, 1790–1930

1790	1800	1810	1820	1830	1840	1850	1860
24,250	30,062	38,145	31,765	39,482	40,996	40,235	47,904

1870	1880	1890	1900	1910	1920	1930
61,432	70,312	84,220	99,687	127,667	153,506	169,304

An examination of the above table seems to indicate a decrease in population between 1810 and 1820 and again between 1840 and 1850. These are explained by the reduction of the size of the county. Parts of Northampton County were taken in 1812 to form Lehigh County, in 1836 for Monroe County, and in 1843 for Carbon County. Actually each decade has shown an increase in population.

Population of the principal towns and cities, 1890–1930

	1890	1900	1910	1920	1930
Bangor	2,509	4,106	5,369	5,402	5,824
Bath	723	731	1,057	1,401	1,625
Bethlehem	6,762	7,293	12,837	50,358	57,892
Chapman	392	319	253	228	232
East Bangor	804	983	1,186	942	991
Easton	14,481	25,238	28,523	33,813	34,468
Freemansburg	615	596	867	1,203	1,777
Glendon	907	704	823	715	615
Hellertown	708	745	915	3,008	3,852
Nazareth	1,318	2,304	3,978	4,228	5,505
Northampton	.....	.....	8,729	9,349	9,839
Northampton Heights	.....	.....	1,037	.....	.....
North Catasauqua	.....	.....	2,030	2,321	2,700
Pen Argyl	2,108	2,784	3,967	4,096	4,310
Portland	676	490	649	545	551
Roseto	.....	.....	.....	1,634	1,746
South Bethlehem	10,302	13,241	19,973	.....	.....
Stockertown	.....	.....	426	432	602
Tatamy	.....	260	512	478	592
Walnutport	.....	.....	1,039	1,051	1,151
West Easton	.....	1,000	1,033	1,408	1,564
Wilson	.....	.....	.....	5,106	8,265
Wind Gap	.....	711	832	1,133	1,388

Population of the Townships, 1890–1930

	1890	1900	1910	1920	1930
Allen	3,474	6,541	822	1,010	1,060
Bethlehem	2,397	3,090	3,414	1,980	2,980
Bushkill	1,644	1,586	1,504	1,460	1,575
East Allen	1,104	1,137	1,345	1,168	1,404
Forks	1,189	1,147	1,132	1,100	1,413
Hanover	440	401	403	393	526
Lehigh	3,570	3,769	3,175	2,668	3,022
Lower Mount Bethel	1,322	1,335	1,890	1,875	1,973
Lower Nazabeth	930	1,034	1,053	1,195	1,597
Lower Saucon	3,913	4,141	3,855	3,430	3,709
Moore	2,544	2,293	2,357	2,128	2,140
Palmer	2,396	2,051	3,059	1,465	2,355
Plainfield	2,521	2,042	2,453	2,581	2,905
Upper Mount Bethel	3,106	2,446	2,857	2,407	2,356
Upper Nazareth	550	736	1,605	1,800	1,824
Washington	2,523	2,614	3,532	1,758	2,061
Williams	2,676	1,819	1,648	1,775	2,045

Urban and rural population of Northampton County, 1900–1930

	1900	1910	1920	1930
Urban	52,662	78,904	104,716	121,525
Rural	47,025	48,763	48,790	47,779

The tables above indicate definite trends in which the agricultural population has remained practically stationary or has declined whereas the urban population, principally concerned with the manufacturing industries, has almost invariably increased. The rural population of Northampton County in 1930 was 128.4 per square mile while for the entire State of Pennsylvania it was 69.0. Some of the decided increases in particular cities such as Bethlehem, Easton and Northampton are explained by the extension of the city limits and by the con-

solidation of boroughs. For example, Bethlehem annexed the borough of West Bethlehem (Lehigh County) in 1904, absorbed the boroughs of South Bethlehem and Northampton Heights in 1920 and, in addition, extended the city limits by taking in parts of Bethlehem and Lower Saucon townships. Some of the decreases in the population of certain townships are similiarly explained by the incorporation of boroughs at the expense of the townships. In a few cases the development of a particular industrial plant or its abandonment has caused an increase or decrease of population. The growth of Nazareth since the establishment of several large cement plants in that section and the decline of Glendon after the closing of the local iron furnaces furnish illustrations of these changes.

Highways.—Northampton County is well provided with highways, thus rendering all parts readily accessible. In the early days there were several privately owned improved turnpikes with toll houses and also toll bridges. All of the turnpikes and most of the bridges have now been taken over by the State or local communities and freed. The improvement of the highways has been very rapid since the appearance of the automobile so that there is now a fine network of hard-surfaced roads, both concrete and macadam, that penetrate all portions of the county. The first concrete pavement in Pennsylvania was constructed on Mauch Chunk Street in Nazareth in 1908. Also the first concrete highway between Pennsylvania cities was the Bethlehem-Easton road built in 1915-1916. Many of the dirt roads have likewise been improved. The main highways are kept open during the winter by snow-plows and there is little interference even after the worst snow-storms. Sleighs, once used extensively, have almost completely disappeared.

In that portion of the county underlain by limestones the roads run in every direction and in most cases bear little relation to the streams and their valleys. In contrast with this situation, in the slate regions, where the irregularities of topography are more accentuated and valleys narrow and steep-sided, the roads are located along the streams and on the stream divides. As the drainage here is along north-south lines the roads are prevailingly in the same direction.

The roads in Williams and part of Lower Saucon townships, where the crystalline rocks are predominant and the hills are of irregular shape, have a less pronounced pattern although they tend to follow the valleys.

Few roads cross Kittatinny (Blue) Mountain on the northern boundary. The gorges cut by the Delaware and Lehigh rivers have been sufficiently widened to permit main highways to pass through

them. The Wind Gap also has been used for an important road leading to the Pocono Mountains. Minor notches in the mountain—Totts Gap, Fox Gap, Smith Gap and Little Gap—have also been utilized.

Railroads.—Several railroad lines cross Northampton County and have aided in the industrial development of the region. The Lehigh Valley Railroad and the Central Railroad of New Jersey closely follow the Lehigh River from Easton to the Lehigh Gap and beyond. Branches of these two railroads tap the cement and slate districts. The Lehigh & New England Railroad traverses cement and slate sections and connects the anthracite fields with New England. Branches also extend to Bethlehem and Allentown.. The Reading Railroad links Bethlehem to Philadelphia. The main line of the Delaware, Lackawanna & Western Railroad takes a short course through the county from Portland to the Delaware Water Gap with branches extending through the slate and cement districts.

The extensive railroad system of the county is largely due to the important slate and cement deposits and the location of the region with reference to Philadelphia and New York in one direction and to the anthracite fields, western New York and central and western Pennsylvania in the other direction. In turn, it may be said that the industrial development of the county is largely due to the fine transportation facilities.

Until recently there were several interurban trolley lines between the principal towns of the county and adjoining regions. Most of these have now been replaced by bus lines and the tracks torn up. The lines between Allentown and Philadelphia, between Allentown and Easton and between Bethlehem and Hellertown still remain. Some of these may be abandoned, entirely or in part.

A canal owned by the Lehigh Coal & Navigation Company follows the Lehigh River from Mauch Chunk to Easton and thence southward along the Delaware River to Philadelphia. Several dams were built to divert river water into the canal, and locks were constructed at these places. These are conspicuous at Allentown, Bethlehem, Island Park, Easton, etc. This canal was built in 1824 and was long used for the transportation of anthracite to Philadelphia and to towns along the route. For several seasons past no canal boats have been in operation and the only purpose of the canal is as a source of water power in a few places.

In the chapters that follow, the rocks, structures and physical features will be described; the forces and agents, both natural and human, that have operated and are still operating in the region will be examined and evaluated; and attempts made to interpret the long and eventful past as recorded in the physical make-up of the county.

EARLY HISTORICAL DEVELOPMENT

By Benjamin L. Miller

Indians.—The region now embraced in Northampton County, when first seen by white men, was sparsely occupied by the Lenni-Lenape (usually shortened to Lenape) or Delaware Indians, a branch of the Algonkians. According to tradition these Indians came from the west and took possession of territory that had still earlier been occupied. The evidence of such residence is vague and extremely unsatisfactory, although several investigators are inclined to believe that some of the stone artifacts that have been so plentifully found throughout the area represent a pre-Algonkian culture. Claims have been made by some archeologists that primitive man occupied the Delaware River Valley during the last invasion of the great glacial ice sheet. This is a fertile field of investigation.

The Lenape Indians were divided into three tribes, two of which shared this area, with the limits of their respective claims indefinite. The southern division, the Unami, whose totem was the Turtle and accordingly known as the Turtle Tribe, claimed the territory from what is now northern Delaware to the Lehigh River, or according to other beliefs to Kittatinny (Blue) Mountain. The Minsi tribe with the Wolf as their totem occupied the region to the north, embracing the headwaters of the Delaware and Lehigh rivers.

It seems fairly certain that the Iroquois Indians pushed into Pennsylvania before the tenth century and gradually supplanted the authority of the Algonkians over much of that territory. When the European settlers appeared in eastern Pennsylvania the Lenape or Delawares had come under the domination of the Iroquois, some tribes of which had banded together to constitute the Five Nations. The Iroquois applied the title of Women to the Lenape, a term which in time became very obnoxious as indicating weakness and inferiority.

The Indians seem to have established few permanent villages within the present confines of Northampton County. The only one of which we have more than the most superficial information is Welagamika, which was located between Nazareth and Schoeneck on the east side of the road connecting these towns. The site seems to have been occupied for some time as the early Moravian settlers found there groves of peach and plum trees and fields of corn and pumpkins. It was with great reluctance that the Indians abandoned the village in 1742.

We have record of another Indian village along Hokendauqua Creek directly east of the present borough of Northampton. This village was called Hochyondocquay. Near this village those who participated in the Walking Purchase spent the night of September 19, 1737. Little information is available concerning this village but it must have been occupied for some time, as numerous Indian graves have been found in excavations in that vicinity.

The Indians seem to have had an especial liking for the junction of major streams, and the Easton locality received the name of Lechauwitank (in the forks). They probably camped there frequently, even if they did not establish a permanent town.

The great abundance of Indian articles found in the vicinity of the junction of Saucon Creek with the Lehigh River is the chief evidence of the more or less permanent occupation of that locality. There is also mention of a settlement in the area of Christian Springs to which the Indians applied the name Nolemattink (where the silkworm spins), but this was probably named after the establishment of Rev. Bader's cocoonery there in 1752.

A village site near Cherryville has also been claimed on account of the great number of artifacts found there. Other places from time to time will undoubtedly be brought to notice, but since no permanent houses or other structures were erected the only way of determining ancient village sites is by an abundance of artifacts and graves. Admittedly, these may have been places of only occasional encampment.

It seems fairly certain that the territory now comprising Northampton County was used by the Indians almost exclusively as hunting and fishing grounds although for these purposes less valuable than the regions north of Kittatinny Mountain. The entire area was covered with trees and shrubs in which were several varieties of oak, maple and other deciduous trees, with few conifers. There were few large trees and such as there were grew along the streams, a condition probably brought about by the occasional forest fires set by the Indians to drive the game through the gaps in Kittatinny Mountain for slaughter by the hunters stationed there in ambush.

So far as known the Indians made almost no use of any of the mineral products of the region other than a limited use of the agricultural soils. Pieces of black flint, chalcedony and quartz were undoubtedly picked up from the surface and fashioned into arrowheads and other objects but these materials are so widespread that one cannot identify specific sources. This is in contrast with Lehigh and Bucks counties where jasper quarries were extensively operated.

White men.—We have no authentic records of the earliest appearance of white men in this section. As early as 1701 a German, John

Steihlman (name variously spelled), is reported to have come into the region with a supply of merchandise, including liquor, to trade with the Indians. William Penn, hearing of this, dispatched two settlers of the lower part of Bucks County to investigate. They discovered Steihlman, confiscated his goods and forced him to leave.

Perhaps the earliest white settlers located in the southern part of Williams and Lower Saucon townships. There is reason to believe that some white men settled in Durham, Bucks County, a few miles from the Northampton County line, as early as 1682 and that gradually others pushed northward into what is now Williams Township and eventually crossed the Lehigh River into "The Forks," the area included between Kittatinny Mountain and the Lehigh and Delaware rivers. Probably several squatter families settled south of the Lehigh River before 1728 when the first group of Scotch-Irish immigrants, under the leadership of Thomas Craig, settled in the region of Weaversville. Even yet that section lying between Bath and Northampton is known as the Irish Settlement. It was also called Craig's Settlement at an early day.

In 1730 another group of Scotch-Irish, numbering 30 families, led by Alexander Hunter, settled in the northeastern part of the county in the vicinity of Williamsburg, Richmond and Martins Creek.

The first of the Moravians reached Nazareth in 1740. The following year they consummated the purchase of a tract where Bethlehem stands and transferred their main activities to this place. From that time settlers spread throughout the area in ever-increasing numbers. They came from many countries but with the German predominant. The many geographic names of German origin bear evidence of the important part they have had in the early development of the region.

The plan which William Penn adopted of purchasing the land from the Indians was continued by his successors. This led to the famous Walking Purchase of 1737 by which the whole of Northampton County as well as additional territory was acquired by Thomas Penn and his associates. Much has been written concerning this historical event and there is wide diversity of opinion with regard to almost every phase. Some years before 1737, the Proprietaries' agents produced a document bearing the endorsement "Copy of the last Indian purchase" which was claimed to be a true copy of a deed made August 30, 1686 and signed by three Delaware Indian chiefs by which William Penn was given a tract of land north of the "Neshaminy Purchase" extending from its northern boundary as far as a man can walk in a day and a half and thence eastward to the Delaware River. This was shown to the Indians in 1737 and reluctantly accepted by them as genuine although they had no previous knowledge of its existence and

all the signatories were dead. The common belief is that the entire instrument was a forgery or an altered copy.

At sunrise on the morning of September 19, 1737 three trained walkers started from a place near Wrightstown. They walked until sundown and resumed the next morning. At noon they had walked about sixty-seven miles, to a point a few miles east of Lehighton. A line later surveyed to the Delaware River gave the Proprietaries a large part of Carbon and Monroe counties as well as all of Northampton County. The walkers probably spent the night near an Indian village on Hokendauqua Creek just east of the present borough of Northampton, although some claim that they passed Blue Mountain before the end of the first day and slept in the woods near an Indian village called Meniolagomeka in the valley of Aquashicola Creek. The route is also in doubt but it seems that they crossed the Lehigh River just below the present site of Bethlehem and proceeded northwest across Monocacy Creek, passing near the sites of Northampton and Walnutport. Most writers state that the walkers passed through Lehigh Gap but others claim that the trail followed passed over Blue Mountain through Smith Gap. Although the records disagree, the writer is convinced that the route was through the Lehigh Gap.

Regardless of whether the purported deed of 1686 was genuine or not, the Indians felt that they had been cheated in that the area covered in the walk was excessive and far greater than intended. One Indian expressed his indignation by saying that the walkers "no sit down to smoke, no shoot a squirrel, but lun, lun, lun all day long." Accordingly the Indians resented the amount of territory covered and refused to vacate the region. However, by 1742 all of the Indians, with the exception of a few individuals, who were granted the privilege to remain, had removed from the present confines of Northampton County. This was accomplished with the assistance of the Iroquois Indians who lived to the north. Resentment against the whites on account of the injustice done to them continued, however, and later culminated in the Indian uprisings in 1755-1758 and 1763-1764, during which times there were many massacres of white settlers in the northern part of the county.

As the region became settled, a movement developed to have a new county formed and by an Act of the Assembly the County of Northampton was formed by separation from Bucks County on March 11, 1752. The new unit embraced not only what now constitutes Northampton County but the area included in the counties of Lehigh, Carbon, Monroe, Pike and Wayne, and parts of Luzerne, Wyoming and Susquehanna. By subsequent acts in 1812, 1836 and 1843 Northampton County was reduced to its present limits.

The population of the large area of Northampton County at the time of its formation was about 5,900, of whom about two-thirds were living within what is the present confine of Northampton County.

The subsequent history of Northampton County does not belong in this work, important though it may be. That part belonging to the development of the industries based on the mineral products of the county will receive attention in the discussion of the individual economic minerals; other historical notes must be omitted.

DEVELOPMENT OF KNOWLEDGE OF THE GEOGRAPHY AND GEOLOGY WITH BIBLIOGRAPHY AND CARTOGRAPHY

By Benjamin L. Miller

The region now embraced within Northampton County has received attention from explorers, travelers, geographers, geologists and historians for 200 years. During this time scarcely a year has passed without some contribution being made. Naturally most of the contributions to knowledge of the geography or geology are fragmentary and of little importance. Some are indefinite or even incorrect, but others are valuable because they set forth ideas or theories on which later investigators could build. Many of the publications are merely repetitions of previously published information. In the bibliography which follows, all kinds of articles are listed regardless of their worth, with the thought that by so doing valuable time of later students may be conserved.

The number of literature references is vastly increased because of the Delaware Water Gap and the Wind Gap being located in part within the county. These two natural phenomena have long served as the finest examples of water gaps and wind gaps and have been described in almost every textbook on geology and geography published in this country and even have been described in many foreign publications. There are probably numerous additional references to them besides those mentioned.

Other features have been described over and over, such as the peneplane of Kittatinny (Blue) Mountain, the Delaware and Lehigh rivers, the slate and cement districts, the iron mines, etc. The minerals of the serpentine rocks along the Delaware River north of Easton have long interested mineralogists and have been described in many publications.

With few exceptions the contributions of the first 100 years consist mainly of maps and occasional notes in books of travel or in historical records. Maclure, Finch, Silliman and Thomson were the principal workers; Maclure in particular laid the foundation for all geological work in the region. He has been called the "Father of North American Geology."

Systematic geologic work began in 1836 with the establishment of the First Geological Survey of Pennsylvania under the direction of Henry D. Rogers. In the Second Annual Report in 1838 we have the first specific references to several different physical and geologic features of Northampton County. In Rogers' succeeding annual reports and in his two voluminous volumes of the Final Report published in 1858 are contained the outlines of the geology of the county as we

conceive it to be today. More detailed studies have been made since that time and many explanations have been modified, yet little change has been made in the basal concepts of Rogers and his co-workers as expressed in their writings between 1836 and 1858.

Between the close of the First Geological Survey and the beginning of the Second Geological Survey in 1874 under the direction of J. P. Lesley, the contributions were of minor importance. The Second Survey extended to 1895. During this time many geologists visited this region and reported their findings, but the major contributions were made by Frederick Prime, Jr., who was especially assigned to the Lehigh Valley. Prime devoted most of his attention to the iron mines, which at that time were being worked most actively. However, he did considerable stratigraphic and structural work in addition to his economic studies.

Since the close of the Second Survey many workers have centered their activities on specific problems of this region. These need not be described here inasmuch as they will receive consideration elsewhere in this volume in the discussions of particular formations, ore deposits, etc. Nevertheless, a few writers are well deserving of mention because of the value of their contributions. Among these are the late Prof. E. H. Williams, Jr., the late Prof. F. B. Peck and Dr. Edgar T. Wherry.

BIBLIOGRAPHY AND CARTOGRAPHY

1685

Budd, Thomas. Good Order established in Pennsylvania and New-Jersey being a true account of the country; with its produce and commodities there made in the year 1685.

Reprinted with notes by Edward Armstrong, 111 pp., New York, 1865.

Mentions the difficulty the Indians had in taking their canoes from the Falls (at Trenton) to the Indian town "Minisincks" (just above the Delaware Water Gap).

1715

Moll, Herman. A New and Exact Map of the Dominions of the King of Great Britain on ye Continent of North America.

London, 1715 (Dedication gives date of 1711). 26"x40". Scale: 1 inch = 60 miles. Moravian Archives.

It appears that no information existed in regard to the regions embraced in Northampton County. The Perquemuck (Schuylkill) River flows almost parallel to the "Dellaware" River to its junction at Philadelphia.

Reading, John, jr. Diary, 1715. In possession of New Jersey Historical Society. Abstracts published in History of Warren County, New Jersey by George Wyckoff Cummins (p. 14-17), New York, 1911.

Contains a brief description of the Delaware Water Gap (Pahackqualong) as "the cleft in the aforesaid mountain where the river passes through" (May 19, 1715).

1735

SCULL, P. JAMES. The Indian Tract Manor. Tract of land situate on the Forks of the Delaware in the County of Bucks containing six thousand five hundred acres and allowance of six per cent.

Taken from the Field Works of Nicolas Scull, deceased. Surveyed. the 24th day of June 1735. 12½"x17". Pennsylvania Archives, 3 ser., vol. IV.

Shows the boundaries of the tract of land that was to have been set apart for the Indians then residing in different parts of the region, located on left bank of the Lehigh River in what is now Lehigh Township.

1740

EASTBURN, BENJAMIN, Surveyor General. A Draught of Sundry Tracts of Lands, surveyed to Divers purchasers in ye Forks of Delaware River, and on, and near the West Branch of said River, in ye County of Bucks.

Drawn in the year 1740, by Benja. Eastburn, Surv'r. Gen'l. 21"x33". Scale: 1 inch = ⅞ mile. Hist. Soc. of Pa., Moravian Archives.

Manuscript map. Shows ownership of various tracts, many belonging to William Allen. The Lehigh River is called the West Branch of the Delaware. "Saucony" Creek. "Menakasie" Creek, "Hockiundaque" Creek, "Lehietan (Bushkill) Creek. Monocacy Creek is shown forking near its union with the Lehigh River. One branch continues the course of the stream and the other as at present. Shorter branch now filled.

Map covers area embracing location of Easton, Bethlehem, Allentown, Coplay, etc.

1749

EVANS, LEWIS. A map of Pensilvania, New-Jersey, New-York and the Three Delaware Counties by Lewis Evans, 1749.

19"x26". Scale: 1 inch = 15 miles. Pennsylvania Archives, 3d ser., app. vol.

"Bethlem" (Bethlehem) and Nazareth are the only settlements shown in Northampton County. Several creeks and the Delaware and Lehigh (called West Branch of the Delaware) Rivers are shown. South Mountain is called "Leheigh Hills."

1752

ANONYMOUS. Northampton County. Map 17½"x19". Scale: 1 inch = 5¾ miles.

Original in Amer. Phil. Soc., Phila. Photostat in Hist. Soc. of Pa. Is dated 1752 but contains much later data such as names of counties (Lehigh, Carbon, Monroe, Pike, etc.) erected long after that date. It is possible that this map was later changed.

A generalized manuscript map which includes the entire territory lying north of Bucks County to the New York State line and westward to the Schuylkill River.

The Indian towns of Welagemeki, situated just north of Nazareth, and Nolamattink at about the locality of Christians Spring are shown. Some early settlements are marked. Blue Mountain given as "Kekachtenemin or Blue Mountain." The route of the Walking Purchase walk is shown through Smith Gap with the termination about five miles south of Stoddartsville. This route is probably inaccurate.

ANONYMOUS. Forks of Delaware & Manor of Fermor, circa. 1752.

14½"x15". Scale not given. Hist. Soc. of Pa. Pen and ink sketch.

The Lehigh River is labelled "West Branch of Delaware."

1753

ANONYMOUS (Probably C. G. Reuter). Bethlehem Tract with all the Adjacent Lands, 1753 (?).

18½"x30". Scale 1 inch = about 3.75 perches. Hist. Soc. of Pa. Pen and ink, partly colored. Scale incorrect; area larger.)

Sawmills on Sand Island along Monocacy Creek. Opposite it along Lehigh River "S. (single) Sr's. washhouse.". "S. (single) Breth. washhouse" along Lehigh River to the west about where silk mill now stands.

1755

ANONYMOUS. Nazareth Tract with the adjacent Lands 1755 (?).

Map 18"x33". Scale: 1 inch = about 60 perches. Hist. Soc. of Pa. Moravian Archives.

Extends from "Lehietan or Tattamy's Creek" (Bushkill) westward to "Manokasy Creek." Shows location of Friedensthal (near site of present town of Tatamy), Gnadenthal (present location of County Poor House), Christians Spring, etc.

Evans, Lewis. A General Map of the Middle British Colonies in America by Lewis Evans. 1755.

Map 20"x26". Scale: 1 inch = 35± miles. Pennsylvania Archives, 3d ser., app. vol. Moravian Archives.

Scale so small that few features are shown. Nazareth, Bethlem (Bethlehem) and Easton are located. Blue Mountain between the Lehigh and Delaware Rivers is called Peaartin (?) (name somewhat illegible) Mountain.

Evans, Lewis. Analysis of a Map of the Middle British Colonies in America.

Second edition, 32 pp., Philadelphia, 1755. First edition, 1749 (?).

Describes in a general way the topography and drainage of the region. Describes the character of the Delaware River. The Lehigh is called the West Branch of the Delaware. "The South Mountain is not in ridges like the Endless Mountains, but in small, broken, steep stony Hills; nor does it run with so much regularity. In some Places it gradually degenerates to Nothing, not to appear again for some Miles, and in others appears several Miles in Breadth. Between the South Mountain and the higher Chain of the Endless Mountains (often for Distinction called the North Mountain and in some Places the Kittatinni and Pequilin), there is a Valley of pretty even, good Land, some 8, 10 or 20 Miles wide, which is the most considerable Quantity of valuable Land that the English are possest of: and runs through New-Jersey, Pennsylvania, Maryland and Virginia. It has yet obtained no general Name, but may properly enough be called Piemont, from its situation. Besides Conveniences always attending good Land, this Valley is every where enriched with limestone." (p. 7.)

1757

Anonymous. (Probably C. G. Reuter). Draught of Bethlehem Lands lying south of the Lehigh (German copy Lecha); i.e., of such as are cleared and fenced—and of the 5 (five) inhabited improvements thereon, with their grounds and fences. Beth'm. July 15, 1757.

17"x42". Scale: 1 inch = about 2 perches. Moravian Archives (in German). Hist. Soc. of Pa. (in English). Pen and ink drawing. Colored. (Scale incorrect; area larger.)

Shows several sink holes. Two of these with streams running in them must be just north of Lehigh University campus. Two sink holes shown along stream that separates Fountain Hill from area to east. Two springs along south side of Lehigh perhaps just above present site of hill-to-hill bridge and another about Northampton Heights.

1758

Anonymous. Map extending from Forks of the Delaware (Easton) to Maccongy (Macungie) north of "Lehi" Hills. "Copy 1758."

11"x15". Scale: 1 inch = 400 perches. Hist. Soc. of Pa.

Not much information.

Golgowfsky, George Wenceszlaus. Friedensthal: A settlement of the Moravian Oeconomy, near the Barony of Nazareth, Northampton Co., Penna. 1758. Surveyed by George Wenceszlaus Golgowfsky. 1752.

10½"x14". Scale not given. A pen and ink drawing. Hist. Soc. of Pa.

Friedensthal is located on east side of Lehietan or Bushkill Creek a short distance northeast of present town of Tatamy. Contains 1 acre 2 roods 1.5 perches. Mill race comes into tract showing there was a mill here.

Reuter, C. G. Historical Map of the Barony Nazareth and its adjacents. Based upon a map by C. G. Reuter, 1758. Hist. Soc. of Pa.

15½"x23½". Scale: 1 inch = 100 rods. Original drawing. Colored.

Shows roads, streams and houses.

Reuter, P. C. G. Historical Map of the Moravian Lands at Bethlehem. Based upon a map drawn by P. C. G. Reuter, March 1758.

14"x17". Scale: 1 inch = 100 rods. Pen and ink drawing. Hist. Soc. of Pa.

Shows location of Nain, about 250 rods west of Monocacy Creek and north of small tributary. "Tile kill" on east side of Monocacy just opposite mouth of small stream coming in from west below Erwin Paint Mill. Scuth Mountain is named "The Lecha Mountain."

1759

Scull, Nicholas. Map of the improved Part of the Province of Pennsylvania by Nicholas Scull. 1759.

30"x60". Scale: 1 inch = 3.8 mile. Pennsylvania Archives, 3d ser., app. vol.

Fairly good map showing the Delaware and Lehigh (called West Branch of tho Delaware) Rivers and Cobus' (Jacobus), Smallys (Mud Run), Lehietan (Bushkill), Manakisy (Monocacy), Saucon, Mill (Catasauqua), Hookyondocque (Hokendauqua), and Fry's (Run) Creeks. Nazareth, Bethlehem, Easton, Lafever (Tatamy), Cruikshanks (Shimersville) and Stophe (?) (illegible on map, located near south part of present borough of Hellertown). Camels Hump is called Manakisy Hill.

1760

Anonymous. A Draught of Several Roads going through Bethlehem Land. 1760.

15½"x16". Scale: 1 inch = 200 perches. Pen and ink drawing. Hist. Soc. of Pa.

Shows location of "Nain, ye Indian Town" on west side of "Manokasy" Creek and north of stream coming in from west, south of present location of paint mill. Brick kiln on east side of Monocacy Creek just south of place where this western tributary comes in. This stream shown heading in spring. Sawmill on Sand Island. Area shows Nazareth, region east of present Freemansburg, "Allen's Town," "Thomas Wilsons Mill" on "Hockiundaqua Creek" about 400 perches above its junction with Lehigh River. Roads to Philadelphia, Easton, Nazareth, Fort Allen, Allentown and Reading are called King's Roads.

Garrison, Nicholas and Kolokofsky (Golgowfsky), George Wenceslaus. A Draft of Four Fording Places over the Lehigh near Bethlehem. Surveyed Oct. 2, 1760 by Nicholas Garrison, Jr. and Geo. Wenceslaus Kolokofsky (Golgowfsky).

12"x33". Four ink sketches. Scale: 1 = about 8.8 rods. Hist. Soc. of Pa.

The upper ford about one mile above Bethlehem near the Geissinger Farm, the lowest two miles below Bethlehem.

1762

Anonymous. Plan of the Moravian Hamlet near Nazareth showing how much of it was surveyed for the 3 residents. Sept. 1761.

14"x20". No scale given. Original drawing. Hist. Soc. of Pa.

Small streams shown and location of farms.

1770

Scull, W. A map of Pennsylvania exhibiting not only The Improved Parts of that Province but also Its Extensive Frontiers laid down From Actual Surveys and Chiefly from the late map of W. Scull, published in 1770.

24"x48". Scale: 1 inch = 6 2/3 miles. Pennsylvania Archives, 3d ser., app. vol.

Shows several streams, Nazareth, Bethlehem and Easton, several mills with names of owners, as well as residences of LeFevre, Waggoner and Jennings. South Mountain is called Leheigh Hills. Camels Hump is Manakisy Hill, Wind Gap is Wind's Gap.

Scull, W. The Province of Pennsylvania, by W. Scull, Philadelphia, 1770. 21"x31". Scale: 1 inch = 9 miles. Pennsylvania Archives, 3d ser., app. vol.

Only a few streams, mountains and towns in Northampton County named. Allentown appears as "Northampton." South Mountain is called "Lehi Hills." Martins Creek is called "Smallys Creek."

Sauthier, C. J. A map of the Provinces of New York and New Jersey with a part of Pennsylvania and the Province of Quebec from the Topographical Observations of C. J. Sauthier. Augsburg, 1777.

29"x40". Scale: 1 inch = 12½ miles. Pennsylvania Archives, 3d ser., app. vol.

Very few names and topographic features in Northampton County. South Mountain is called "Leheihg Hills" possibly a typographical error and intended for Leheigh.

1779

ANONYMOUS. Map of Gen. Sullivan's march from Easton to the Seneca & Cayuga Counties.

Ms. 28"x30" (1779?). Hist. Soc. of Pa. (?) Later failed to locate the map here.

1786

CHASTELLUX, MARQUIS DE. Voyages de M. Le Marquis de Chastellux dans l'Amerique Septentríonale dans les annêes 1780, 1781 & 1782.

Two volumes, 390 pp. and 362 pp. Paris 1786.

See Chastellux, 1827.

1788

SCHÖPF, JOHN. Reise durch eínige der mittlern und südlichen vereinigten nordamerikanischen Staaten. Unternommen in den Jahren 1783 und 1784.

Two parts, Erlangen 1788. Translated with title, Travels in the Confederation (1783-1784), and edited by Alfred J. Morrison, 2 vols., 426 pp., 344 pp., Philadelphia, 1911.

See Schöepf, 1911.

1792

HOWELL, READING. A Map of the State of Pennsylvania by Reading Howell, 1792.

36"x62". Scale: 1 inch = 5 miles. Pennsylvania Archives, 3d ser., app. vol. Moravian Archives.

Shows courses of Delaware and Lehigh Rivers, Cobus' (Jacobus), Martins, Smalley's (Mud Run), Lehietan (Bushkill), Fry's (Frya) Run, Saucon, Nancy's Run, Manakisy (Monocacy), Mill and Hockyondocque (Hokendauqua) Creeks. Foul Rift is located. A number of dwellings and mills are located, some of which are named. The name Wind Gap appears on map.

1794

CAZENOVE, THEOPHILE. Journal, Manuscript in French.

75 pp., 1794. Translated from the French by Rayner Wickersham Kelsey, 103 pp. and map. Haverford, 1922.

See Kelsey, 1922.

LOSKIEL, GEORGE HENRY. History of the Mission of the United Brethren Among the Indians in North America.

Translated from the German by Christian Ignatius LaTrobe. Three parts, 159, 234, 233 pp. Index and map. London, 1794.

Contains some items of geographic interest. An excellent account of the Indians that formerly occupied this region.

1795 circa

ALLUM, JOHN AND WALLIS, JOHN. Map exhibiting a General View of the Roads and Inland Navigation of Pennsylvania and part of the adjacent States, by John Allum and John Wallis.

29½"x33". Scale: 1 inch = 9 miles. Pennsylvania Archives, 3d ser., vol. 1.

Very few places named in what is now Northampton County. What is now Allentown appears as "Northampton." A creek possibly the present Hokendaqua is called "Bostons Creek." A ferry just below mouth of Hokendaqua Creek is named "Fousts Ferry." Lehigh River appears as "Lehi River."

1798

J. H. Original Account of the Borough of Easton in Pennsylvania.

Philadelphia Mo. Mag. September 1798. pp. 113-115.

Contains following statement showing utilization of water power of Bushkill Creek. "On Bushkill Creek, which empties into the Delaware, on the north side of Easton, and over which a fine stone bridge is erected, are four grist mills, four sawmills, one oil mill, and two bark mills, with three tanneries, where business is carried on very extensively."

1800

ANONYMOUS. Draught of the Town and Land of New Nazareth in the year 1800.

14"x17". Manuscript map colored. Hist. Soc. of Pa.

Gives names of owners of lots.

THOMSON, CHARLES. Observations.

Appendix No. 1 of Jefferson's (Thomas) Notes on the State of Virginia, 194 + 53 pp., Baltimore, 1800.

"From the best accounts I have been able to obtain, the place where the Delaware now flows through the Kittatinny Mountain, which is a continuation of what is called the North-ridge, or mountain, was not its original course, but that it passed through what is now called "the Wind-gap," a place several miles to the westward, and above a hundred feet higher than the present bed of the river. This Wind-gap is about a mile broad, and the stones in it such as seem to have been washed for ages by water running over them. Should this have been the case, there must have been a large lake behind that mountain, and by some uncommon swell in the waters or by some convulsion of nature the river must have opened its way through a different part of the mountain, and meeting there with less obstruction, carried away with the opposing mounds of earth, and deluged the country below with the immense collection of waters to which this new passage gave vent. There are still remaining and daily discovered, innumerable instances of such a deluge on both sides of the river, after it passed the hills above the falls of Trenton, and reached the champaign." (p. 2 of Appendix.)

Also quoted in Chastellux's travels (1827).

1803

VOLNEY, C. F. Tableau du climat et du sol des Etats-Unis d'Amerique.

2 vols., 532 pp., maps, Paris, 1803.

Translated by C. B. Brown and published under the title "A view of the soil and climate of the United States of America." 446 pp., maps, Philadelphia, 1804.

Refers to the trend of the mountain ridges of the Appalachians and remarks "it is very remarkable, that these ridges strike the course of the Atlantic rivers at right angles, the streams rushing through them at gaps or breaks, which have evidently been made by the force of their waters."

Also contains a discussion of climatic factors of Pennsylvania.

1804

REICHEL, CHARLES GOTTHOLD. Meteorological Observations made at Nazareth, in Pennsylvania. for the year 1793.

Philadelphia Med. and Phys. Jour., part I, vol. 1, pp. 107-109. Phila. 1804.

Gives readings of temperature, pressure, humidity, prevailing winds and state of weather.

1805

OGDEN, JOHN C. An Excursion into Bethlehem & Nazareth in Pennsylvania, in the year 1799.

167 pp., Philadelphia, 1805. Earlier edition published in 1800.

Describes the Bethlehem spring and the water works, the manufacture of tile for stoves, the making of clay pipes, the island (Calypso), the dry land between Bethlehem and Nazareth with no streams or springs, Christian Spring and the settlement there, the large spring at Allentown.

Describes a search for coal near Nazareth by means of an auger. Says a black earth near Nazareth had been ground and mixed with oil to form a paint.

1807

MEASE, JAMES. A Geological Account of the United States.

510 pp., Philadelphia, 1807.

Gives several brief descriptions of the topography and geology of the Lehigh Valley. Says "the limestone generally lies in a state of confusion, and as it were jumbled together by violence." (p. 46.) A short description of the Delaware River.

1809

MACLURE, WILLIAM. Observations on the geology of the United States, explanatory of a geological map.

Am. Philos. Soc. Trans., vol. 6, pp. 411-428, map, Philadelphia, 1809. Journal de physique, de chimie, d'histoire naturelle et des arts; vol. 69, pp. 204-213, Paris, 1809.

Has brief references to tbe distribution of tbe "Primitive" (pre-Cambrian) crystalline rocks and the "transition" (Lower Paleozoic) sedimentary rocks of eastern Pennsylvania with mention of localities near Betblehem and Easton. The accompanying generalized geological map is tbe first to show tbe regions of Lebigb and Nortbampton Counties.

1811

HOWELL, READING. A Map of the State of Pennsylvania.

22″x33″, 1811.

Townships of Northampton County (wbich at that time included wbat is now Lehigb and portions of Carbon and Monroe Counties) are named. A few towns are also named.

1816

CLEAVELAND, PARKER. An elementary Treatise on Mineralogy and Geology.

First edition, xii + 668 pp., Boston, 1816.

Mention of opal near Easton on the Delaware (p. 225).

1817

MACLURE, WILLIAM. Observations on the geology of the United States of America. 127 pp., map, Philadelphia, 1817.

Review by C. S. Rafinesque, Am. Mo. Mag., vol. 3, pp. 41-44, New York, 1818.

Has brief references to distribution of the "primitive" (pre-Cambrian) crystalline rocks and the "transition" (Lower Paleozoic) sedimentary rocks of eastern Pennsylvania, with mention of localities near Bethlehem and Easton.

1818

HALL, LIEUT. FRANCIS. Travels in Canada and the United States in 1816 and 1817.

337 pp., Boston, 1818.

Describes briefly the topograpby and scenery of a part of Northampton County (pp. 164-166). "I passed the Blue Ridge at the stupendous fissure of the Wind Gap, where the mountain seems forcibly broken through, and is strewn with the ruin of rocks."

MACLURE, WILLIAM. Observations on the geology of the United States of America.

Am. Philos. Soc. Trans., new ser., vol. 1, pp. 1-91, map, Philadelphia, 1818.

Has brief references to distribution of the "primitive" (pre-Cambrian) crystalline rocks and the "transition" (Lower Paleozoic) sedimentary rocks of eastern Pennsylvania, witb mention of localities near Bethlehem and Easton.

MITCHILL, SAMUEL L. Observations on the Geology of North America.

Appendix to Georges Cuvier's "Essay on the Theory of the Earth," pp. 321-431, New York, 1818.

Advances the idea that there were "barriers which probably restrained tbe waters, in some parts of North America, after tbe Ancient Ocean had retired." Believes that Blue Mountain was such a barrier or dam "by which the waters were restrained for a considerable time." In describing the Delaware Water Gap he says "the vastness of the dismemberment impresses every traveller witb a sense of its present grandeur, and of the prodigious force necessary to rend tbe mountain from its summit to tbe base." Lehigh Gap was formed in a similar way. Before the bursting of tbe mountain at Lehigh Gap and Delaware Water Gap, tbe water of tbe sea was partially discbarged through tbe Wind Gap.

1821

WILSON, J. W. Bursting of Lakes through Mountains.

Am. Jour. of Sci. and Arts, vol. 3, pp. 252-253, New Haven, 1821.

Opposes the theory of C. F. Volney and others that Lake Ontario extended at one time to South Mountain and that its waters burst through below Easton simultaneously with the breaking through at West Point, Reading, below Harrisburg, and Harpers Ferry. Confuses South Mountain and North or Blue Mountain.

"Is it not the best theory of the earth, that the Creator, in the beginning, at least at the general deluge, formed it with all its present grand characteristic features?" p. 253.)

1822

CLEAVELAND, PARKER. An Elementary Treatise on Mineralogy and Geology.

Second edition revised, two vols., 818 pp., Boston, 1822.

Brief descriptions of some minerals from Lehigh and Northampton Counties.

1824

FINCH, J. A Sketch of the Geology of the Country near Easton, Penn., with a Catalogue of the Minerals, and a map.

Am. Jour. of Sci. and Arts, vol. 8, pp. 236-240, New Haven, 1824.

Gives a short description of the "Sienitic range of the Lehigh" listing thirteen minerals; the "sienite" serpentine and steatite of Chestnut Hill listing 31 minerals; the "transition limestone" listing 7 minerals; and the "diluvial formation" listing 4 minerals. Says that slate quarries have been opened in the "transition clay slate near the banks of the Delaware" but the product is inferior.

1825

MELISH, JOHN. Map of Pennsylvania constructed from the County Surveys authorized by the State and other original documents, 1825. Revised edition in 1832.

52"x75". Scale: 1 inch = 5 miles.

Names townships, towns, streams. Contains insets giving "statistical and geological remarks." Gives "South Mountains" or "Lehigb Hills." Spellings: "Hectown," "Howartown," "Edmonds," for what is now Schoeneck.

ROBINSON, SAMUEL. A Catalogue of American Minerals with their localities, etc.

316 pp., Boston, 1825.

Lists many minerals from Northampton County, especially in the vicinity of Easton, including opal and flint, prase, tourmaline, epidote, sahlite, hornblende, chlorite, "native magnet," magnetite, various iron oxides, etc. Most of the information was taken from Cleaveland's "Mineralogy."

1826

WATSON, DR. JOHN. Account of the First Settlement of the Townships of Buckingham and Solebury, in Bucks County, Pennsylvania.

Pennsylvania Hist. Soc. Memoirs, vol. 1, pp. 277-311, Philadelphia, 1826, Abstract, Register of Pennsylvania by Samuel Hazard, vol. 3, pp. 406-409, 1829.

"It is also supposed that the Delaware once flowed over the top of the Blue Mountain, and that there was a great lake on the north side of it; that the fall of a great southerly storm of rain, at the breaking up of winter, and melting of a deep snow, has so raised the waters that the obstruction of the water gap at the mountain was suddenly borne away, causing a vast rise of the waters below, and producing proportionable effects." (pp. 284-285.)

1827

CHASTELLUX, MARQUIS DE. Travels in North-America in the years 1780-81-82 by the Marquis de Chastellux. A translation of Voyages de M. Le Marquis de Chastellux dans L'Amerique Septentrionale dans les annees 1780, 1781 & 1782.

Two volumes, 390 pp. and 362 pp. Paris 1786. Translated "from the French by an English gentleman" with notes by the translator. 416 pp., New York, 1827.

The Delaware Gap is described and the settlements of Easton and Bethlehem. In the translation Charles Thomson's descriptions of the Delaware Water Gap and the Wind Gap are quoted and there are further descriptions of places in the region in the form of foot notes.

1828

PRESTON, SAMUEL. Hypothesis on the formation of the Water Gap in a letter to the editor.

The Register of Pennsylvania by Samuel Hazard. vol. 1, p. 424, Philadelphia, 1828.

Believes that Kittatinny Mountain once formed a dam that held back water to form a large lake on the north side. "It appears that the dam must have been sunk into some very tremendous subterranean cavern, and to a depth that cannot be known or estimated."

"If any persons think my hypothesis erroneous, the *Water Gap will not run away,* they may go and examine for themselves."

THOMSON, THOMAS. Chemical Examination of some Minerals, Chiefly from America. With notes by John Torrey.

Lyceum of Nat. Hist. Annals, vol. 3, pp. 9-86, New York, 1828.

Gives an analysis of greenish-yellow precious serpentine from Easton.

1829

ROYALL, ANNE. Pennsylvania or Travels Continued in the United States.

2 vols., 276 and 273 pp. with app. (24 pp.), Washington, 1829.

A few general geographic descriptions along the route from Easton to Bethlehem to Lehigh Gap.

1830

TANNER, H. S. Map of Northampton and Lehigh Counties, Pennsylvania, 1830.

18½"x21". Scale: 1 inch = 2½ miles. Hist. Soc. of Pa.

Includes what is now Carbon and Monroe Counties as well as the present Northampton and Lehigh Counties. A generalized map. Has some unusual spellings and a number of place names not in use now.

1831

SILLIMAN, BENJAMIN. Notes on a journey from New Haven, Conn., to Mauch Chunk and other Anthracite regions of Pennsylvania.

Am. Jour. Sci. and Arts, vol. 19, pp. 1-21, New Haven, 1831. Abstract, Register of Pennsylvania by Samuel Hazard, vol. 6, pp. 273-278, 1830.

Gives a description of the Lehigh River and particularly of the Lehigh Gap. Does not believe that the gap was mainly cut by the Lehigh River. Mentions the presence of serpentine, and fine crystals of mica and zircon near Easton.

1832

GORDON, THOMAS F. A Gazetteer of the State of Pennsylvania.

Part First 63 pp., Part Second 508 pp., map, Philadelphia, 1832.

Contains a brief description of the Lehigh Valley principally abstracted from William Maclure's report (1818). A short description of each of the named geographic features of Northampton County. Curious and erroneous explanations of the phenomena at Delaware Water Gap.

1833

FINCH, I. Travels in the United States of America and Canada, etc.

455 pp., London, 1833.

"A variety of minerals are found near Easton; the rocks consist of sienite, serpentine, and limestone. In one place, the roads are repaired with talc, and some stone walls which divide the fields are made of large masses of fibrous and glassy tremolite, talc and steatite. A quarry of the latter mineral has been opened . . . I went to collect minerals, two miles from the town . . . We found green and white sahlite, augite, scapolite, tourmaline, jade, saussurite, and zircon." (p. 103.) Mentions the water gaps, Wind Gap, flat top of Blue Mountain and other topographic features. Calls the sandstones of Blue Mountain "old red sandstone" (p. 110). Contains a poem praising the beauties of Easton and its environs. (pp. 101-102.)

1835

EATON, REBECCA. A Geography of Pennsylvania for the Use of Schools, and Private Families.

264 pp., Philadelphia, 1835.

Contains brief descriptions of some of the geographic features of Northampton County.

1838

ROGERS, HENRY D. Second Annual Report on the Geological Exploration of the State of Pennsylvania.

93 pp., columnar section and table (Two editions with slight differences). Harrisburg, 1838.

Describes sandstone (Hardyston) of South Mountain (pp. 20-23), limestones and iron ores of the Kittatinny Valley (pp. 23-30), slates (pp. 30-36), sandstones and conglomerates of Blue Mountain (pp. 36-39). Descriptions of specific iron mines, slate and limestone quarries, paint and clay deposits. Explains Delaware Water Gap and other water gaps as due to "transverse dislocations." (p. 79.)

1839

ROGERS, HENRY D. Third Annual Report on the Geological Survey of the State of Pennsylvania.

119 pp., Harrisburg, 1839.

Brief descriptions of the Paleozoic sandstones and limestones of South Mountain and the small valleys lying southeast of Kittatinny Valley, such as Saucon Valley.

1841

DILLINGER, JACOB, BRICKENSTEIN, JNO. C. AND HÜBENER, ABRAHAM. Plan of Bethlehem from Surveys made by Jacob Dillinger, Jno. C. Brickenstein and Abraham Hübener. Drawn by P. Jarrett, 1841.

21"x29". Scale: 1 inch = 160′. Hist. Soc. of Pa.

Shows location of Luckenbach grist mill and foundry where "Manockisy" Creek passes under canal at upper end of Sand Island. Oil mill at waterworks, sawmill and woolen factory near east end of Sand Island (not named on map) close to Manockisy Creek.

ROGERS, HENRY D. Fifth Annual Report on the Geological Survey of Pennsylvania.

179 pp., Harrisburg, 1841.

Contains descriptions of the gneisses, serpentines, and Paleozoic sandstones and limestones of the southern portion of the county (pp. 16-30). Describes some iron mines (pp. 39-43) and a few occurences of the Triassic conglomerates (pp. 43-45). Contains three analyses of iron ore (pp. 108-110) and six analyses of limestones (pp. 159-160).

1843

MAXIMILIAN, PRINCE OF WIED. Travels in the Interior of North America (1832-1834) Translated from German by H. Evans Lloyd.

520 pp., London, 1843.

Occasional brief notes on the topography of the region and the rocks observed in his travels.

TREGO, CHARLES B. A Geography of Pennsylvania containing an account of the history, geographical features, soil, climate, geology, botany, zoology, population, education, government, finances, productions, trade, railroads, canals, etc. of the State; with a separate description of each county and questions for the convenience of teachers.

384 pp., Phila. 1843.

1845

RUPP, I. DANIEL. History of Northampton, Lehigh, Monroe, Carbon and Schuylkill Counties.

554 pp., illustrations. Harrisburg, 1845.

Contains many descriptions of the topographic and geologic features of Northampton County, among which the following topics are of especial interest: The

Wind Gap (Die Wind Kaft) (pp. 25-26), Vint Gap (p. 75), Little Gap (Die Kleine Kaft), Delaware Water Gap (pp. 26-29), and the Lehigh Water Gap (pp. 113-115); and suggests strange explanations for their origin. The Delaware River (pp. 29-30), the Lehigh River (pp. 111-113) and great floods of the Lehigh and Delaware in November 1840 and January 1841 (pp. 53-58, 84); water supplies, Easton (p. 53), Bethlehem (p. 83), Nazareth Spring (p. 78); roofing slate (pp. 59, 64, 75), iron ores (pp. 69, 71).

1850

ANONYMOUS. Map of Easton and South Easton.

14"x21". No date (probably about 1850). No scale.

Childs & Inman's Press. Hist. Soc. of Pa.

Shows locks of canal and dam at mouth of Lehigh River.

HENRY, M. S. Map of Northampton County, Pennsylvania.

28"x35". Scale: 1 inch = ¾ mile. In color.

Printed by H. Camp. 1850. Hist. Soc. of Pa.

Locates 122 mills most of which are sawmills and grist mills. Some are oil mills, some fulling mills and some clover mills. Twenty-two distilleries are located, nine tanneries. Iron ore mines and taverns are shown. States that first furnace for smelting iron in the county was built in 1825.

SIDNEY, J. C. Plan of the Township of Bethlehem, Northampton Co., Penna.

Surveyed by J. C. Sidney, C. E., 1850. Published by Richard Clark, Phila.

23"x31". Scale: 4½ inches = 1 mile.

Locates towns, streams, limekilns, mills and names of farm owners.

1854

GRAILICH, JOSEPH. Untersuchungen uber den ein-und zweiaxigen Glimmer Sitzungsberichte Kaiserlichen Akademie der Wissenschaften, vol. II, pp. 46-87, Wein, 1854.

Describes crystallography of mica from Easton.

1855

GENTH, FREDERICK A. Contributions to Mineralogy.

Am. Jour. Sci. and Arts, 2d ser., vol. 19, pp. 15-23, New Haven, 1855.

Allanite from Bethlehem, analysis (p. 21).

ROEPPER, W. TH. Map of Bethlehem and the new town of Wetherill, Northampton County, Pa.

Scale: 1 inch = 400 feet. Press of P. S. Duval & Co., Philadelphia. 1855. Folded in cloth-bound cover.

In margin of map are views of the Pennsylvania and Lehigh Zinc Works, Upper (Calypso) Island, and first house in Bethlehem.

Map shows Dr. Oppelt's Hydropathic Institute (five buildings, where St. Luke's Hospital is now situated). The large spring of Upper (Calypso) Island is located along eastern shore.

SCOTT, J. D., Publisher. Map of Easton and twelve miles around. Philadelphia, 1855.

44"x50". Scale: 1.55 inches = 1 mile. Philadelphia Public Library.
Shows geographic features and names of property owners.

SMITH, SANDERSON. On some new localities of Minerals.
Am. Assoc. Adv. Sci. Proc., vol. 9, p. 188, 1855.
Crystallized serpentine north of Easton at the nephrite locality.

1857

ROBERTS, SOLOMON W., Chief Engineer. Map Showing the Route of the North Pennsylvania Rail Road from Philadelphia to Bethlehem with its Branches to Doylestown and Freemansburg and its connections with the Lehigh Valley Rail Road. January 1857. Road opened to the Lehigh River Jan. 1, 1857.

24"x48". Scale: 1 inch = 2½ miles. Hist. Soc. of Pa.

A generalized map.

WILLIAMS, W. A Geological and Topographical Map of Pennsylvania and New Jersey compiled from the official reports of the Geological Surveys, public and private. Published by Charles Descher, Philadelphia, 1857.

38"x52". Scale: 1 inch = 8 miles.

Geological formations are hand colored. Is based on Rogers' map. Bears statement that it was "submitted for correction to J. Peter Lesley . . . who constructed the maps and sections of the Geologioal Survey of Pennsylvania."

1858

ROGERS, HENRY DARWIN. The Geology of Pennsylvania.

Vol. 1, 586 pp., Vol. II, 1045 pp., geological map of the State, sections, etc. Philadelphia, 1858.

Many descriptions of geological features of Northampton County. The following are the most important: Vol. I, Lehigh and Delaware Rivers (pp. 43, 47), metamorphic rocks (pp. 92-96, 98), section from Easton to Monroe (99), Primal (Hardyston) sandstone (p. 196), limestones and shales (pp. 232, 237-250), iron ores (pp. 253-266), structure in Blue Mountains (pp. 283-288). Geological section at close of volume, Plate of Lehigh Gap (p. 489). Vol. II, minerals (pp. 710-712), iron ore (pp. 715, 722, 726-728). Cut of Delaware Water Gap (p. 896).

1859

BLODGET, LORIN, Secretary. Twenty-sixth Annual Report of the Philadelphia Board of Trade.

226 pp., Philadelphia, 1859.

"In the Lehigh district most of the furnaces have continued in blast through the whole period of disaster to the trade generally, the demand for their iron, which is of superior quality, and has almost entirely displaced the Scotch pig for the use of founders, being such as to keep them steadily employed." (p. 113.) Annual anthracite furnace production of iron for three years in the Lehigh Valley, twenty out of twenty-four furnaces in operation: 1856—121,021 tons; 1857—113,299 tons; 1858—100,000 tons.

LESLEY, J. P. The Iron Manufacturer's Guide to the Furnaces, Forges and Rolling Mills of the United States.

772 pp., New York, 1859.

Contains numerous descriptions of the iron mines, furnaces and forges of Northampton County.

1860

HENRY, M. S. History of the Lehigh Valley.

436 pp., illustrations, Easton, 1860.

Numerous references to various geological features of Northampton County. Reports the occurrence of "yellow serpentine in great profusion, topaz, beryl, chalcedony; and other precious stones" in the hill north of Easton. Water Works of Easton (pp. 123-125), Water Works of Bethlehem (p. 233). Iron mines and iron works (pp. 162-168). Lime (pp. 168-169). Pottery and tile manufacture at Bethlehem (p. 205). Slate (p. 308). Lehigh Water Gap (pp. 308-310). Lehigh Coal and Navigation Co. and Lehigh Canal (pp. 375-394, 412-416).

HENRY, MATTHEW S. History of Northampton County, Pennsylvania.

(Unpublished). Five volumes of manuscript in author's hand writing, written apparently between 1851 and 1860. Certain portions bear date of 1851. In library of The Hist. Soc. of Pa., Philadelphia.

Contains many descriptions of geologic character.

HITCHCOCK, EDWARD. Illustrations of Surface Geology.

Smithsonian Contributions to Knowledge, 155 p., 12 plates, Washington, 1857, 2nd edition 1860.

Brief description of the Delaware Water Gap. Suggests that at one time the river from the gap flowed northeastward into the Hudson River (p. 111). (Refers to Macculloh's Geographical Dictionary.)

HOPKINS, JR., G. M. Map of Northampton Co., Pennsylvania.

56½"x58". Scale: 1 inch = 1⅝ miles.

Smith, Gallup & Co., Publishers, Philadelphia. Hist. Soc. of Pa.

A detailed map; gives names of owners of land, locates iron mines, quarries, brick yards and other industries. Enlarged maps of principal towns given in insets.

1863

ANONYMOUS (Possibly Thomas Scattergood).

Incidents of the Freshet in the Lehigh River, Sixth Month, 4th and 5th, 1862.

56 pp., Philadelphia, 1863. Pennsylvania Hist. Soc. and Moravian Archives.

Descriptions of flood conditions and damage done.

1864

ANONYMOUS.

Guide-Book of the Central Railroad of New Jersey and its connections through the coal-fields of Pennsylvania.

120 pp., New York, 1864.

Contains some interesting descriptions of tbe features and industries of the Lehigh Valley.

PERCY, JOHN. Metallurgy; Iron and Steel.

934 pp., London, 1864.

Brief description of the iron furnaces along tbe Lehigb River.

1865

BUDD, THOMAS. Good Order established in Pennsylvania and New-Jersey being a true account of the country; with its produce and commodities there made in the year 1685.

Reprinted with notes by Edward Armstrong, 111 pp., New York, 1865.

See Budd, Tbomas, 1685.

1866

RAMMELSBERG, CARL F. Analyse der Glimmer von Uto und Easton und Bemerkungen uber die Zusammensetzung der Kaliglimmer uberhaupt. Zeitschrift der Deutschen geologischen Gesellschaft, vol. 18, pp. 807-812, Berlin, 1866.

Contains an analysis of a specimen of mica from Easton.

1869

BAUER, MAX. Untersuchung uber den Glimmer und verwandte Minerale. Annalen der Physik und Chemie (J. C. Poggendorff), vol. 138, pp. 337-370, Leipzig, 1869.

Describes biotite from Easton.

MARTIN, JOHN HILL. Historical Sketch of Bethlehem in Pennsylvania, with some account of the Moravian Church.

191 pp., Philadelphia. First edition 1869, second edition 1873.

Some account of the early industries of tbe region witb descriptions of the many geographic features. Says that name of island (Calypso) in the river was properly Catalpa from the number of catalpa trees there. A good description of the spring which formerly supplied Bethlebem with water and of the first water works (pp. 28-29), the first tile and brick manufactory established in 1742 about a mile north of Bethlehem on the "Manockasy" (p. 33), a quoted anonymous geographical description of Northampton County (pp. 132-134) published in 1869 in which tbe following statement appears: "The Delaware and Lehigb Rivers botb pass through this mountain (Blue) by gaps apparently torn by the mighty force of the gushing waters from tbe country above." Descriptions of tbe Lebigb River and Lebigb canal (pp. 147-150).

1870

BRODHEAD, L. W. The Delaware Water Gap; its Scenery, its Legends and Early History.

Second edition, 276 pp., 1 plate, Philadelphia, 1870. First edition, 220 pp., 1867.

An appreciative description of tbe Delaware Water Gap witb a fantastic explanation of its origin. Is believed to have been formed by tbe pressure of the waters of a great lake breaking througb tbe rocks of tbe mountain.

1872

HECKEWELDER, JOHN. Names which the Lenni Lennape or Delaware Indians gave to Rivers, Streams and Localities within the States of Pennsylvania, New Jersey, Maryland and Virginia with their significations.

Prepared from a manuscript of John Heckewelder by William C. Reichel.

Moravian Hist. Soc. Trans., vol. 1, pp., 225-282, Nazareth, 1872.

Gives meaning of a number of Indian names applied to geographic features of Northampton County.

C., L. (Probably Chamberlain, Lloyd). Guide-Book of the Lehigh Valley Railroad and its several branches and connections; with an account, descriptive and historical, of the Places Along their Route.

175 pp., Philadelphia, 1872.

Numerous facts concerning the physical features and industries of the Lehigh Valley.

REICHEL, WM. C. The Crown Inn, near Bethlehem, Pennsylvania, 1745.

162 pp., Philadelphia, 1872.

Gives a short description of the Lehigh Valley and North Pennsylvania Railroads. Contains "map, showing the condition of the 'Moravian Tract' on the south side of the Lehigh, opposite Bethlehem, at various times. Based upon Wm. Th. Roepper's map of said tract, drawn in 1854, and on drafts drawn by C. G. Reuter and others in 1753 and 1757 and by G. W. Golkowfsky in 1760; and so prepared as to illustrate the history of the old Crown Inn." Gives origin of Monocacy, Hockendauqua, Lecha (Lehigh), Macungie, Saucon. Gives a short description of the Bethlehem Iron Company.

1873

ANONYMOUS. Guide Book of the Lehigh Valley Railroad and its several branches and connections; with an account, descriptive and historical of the places along their route; including also a history of the company from its first organization, and interesting facts concerning the origin and growth of the coal and iron trade in the Lehigh and Wyoming regions.

186 pp., map, Philadelphia, 1873.

Contains a number of brief descriptions of the mines and mineral industries of Lehigh and Northampton Counties.

1874

BEERS, D. G. Atlas of Northampton County, Pennsylvania.

91 pp., maps, Philadelphia, 1874.

Maps of each township showing location of slate, cement and limestone quarries, lime kilns, iron ore mines and iron works and brick yards.

1875

GENTH, F. A. Preliminary Report on the Mineralogy of Pennsylvania.

Pennsylvania Second Geol. Survey, Report B, 238 pp., Harrisburg, 1875.

Lists the following minerals, giving localities, descriptions and, in some instances, analyses: Graphite (p. 8), chalcocite (p. 16), pyrite (p. 20), marcasite (p. 20), cuprite (p. 30), martite (p. 35), spinel (p. 37), magnetite (p. 38), pyrolusite (p. 46), turgite (p. 47), goethite (p. 48), limonite (pp. 49-50), psilomelane (p. 53), wad (pp. 53-54), quartz (pp. 56-58), prase (p. 59), basanite (p. 60), jasper (p. 60), tremolite (p. 64), actinolite (p. 68), asbestos (p. 69), garnet (p. 75), zircon (p. 76), allanite (pp. 76, 80), epidote (p. 79), tourmaline (p. 97), titanite (p. 110), talc, steatite (p. 111), serpentine (pp. 115, 116), halloysite (p. 122), prochlorite (p. 133), epsomite (p. 149), calcite (p. 154), magnesite (p. 158), siderite (pp. 159-161), lanthanite (p. 165), malachite (p. 167).

PRIME, FREDERICK, JR. On the Occurrence of the Brown Hematite Deposits of the Great Valley.

Am. Jour. Sci. and Arts, 3rd ser., vol. 9, pp. 433-440, New Haven, 1875.

General discussion of iron ores of Great Valley, with special reference to lines of outcrop and cause of accumulation of ore. Mention of damourite-slates and theories of siderite replacement of limestone. Siderite near Hellertown (p. 439).

PRIME, FREDERICK, JR. On the Occurrence of the Brown Hematite Deposits of the Great Valley.

Am. Inst. Min. Eng. Trans., vol. 3, pp. 410-422, Easton, 1875.

Describes the limonite ores of the Great Valley. Says they were probably formed by the oxidation of iron pyrites but not *in situ*.

SHEAFER, P. W. and others. Historical Map of Pennsylvania.

26 pp., 1 col. map 23"x40". Hist. Soc. of Pennsylvania, Philadelphia, 1875.

A number of early geographic names are given. Contains several errors.

1876

HALL, CHARLES E. Notes on Glacial Action Visible along the Kittatinny or Blue Mountain, Carbon, Northampton and Monroe Counties, Pennsylvania.

Am. Philos. Soc. Proc., vol. 14, pp. 620-621, Philadelphia, 1876.

A brief description of evidences of glaciation near Lehigh Gap, Wind Gap and Delaware Water Gap.

LESLEY, J. PETER. On Former Mountain Ranges in Southeastern Pennsylvania.

Am. Philos. Soc. Proc., vol. 14, pp. 436-437, Philadelphia, 1876.

An explanation of the structural geology of two Azoic mountain ranges of southeastern Pennsylvania. The gneiss and mica-slate belt from Easton through Philadelphia, Delaware and Lancaster Counties toward Baltimore. The Easton end is a nose of a plunging anticline of the Azoic rocks.

1877

FRITTS, PETER. History of Northampton County, Pennsylvania.

293 pp., Philadelphia, 1877.

A short description of the geology of the county by Frederick Prime (p. 414). A foot-note states that a "company for obtaining slate from quarries in Northampton County" was incorporated in 1805. Describes Glendon Iron Works where first furnace was erected in 1843 (pp. 228-229). Described nearly all the early iron mines and slate quarries of county. Many references to the geology.

RAU, ROBERT. Historical Sketch of the Bethlehem Water Works, Bethlehem, Pa.

10 pp., Bethlehem, 1877.

Contains a description of the Bethlehem Spring.

1878

FRAZER, PERSIFOR, JR. Remarks on Prof. Prime's Paper (on the Paleozoic Rocks of Lehigh and Northampton Counties, Pa.)

Am. Philos. Soc. Proc., vol. 17, pp. 255-258, Philadelphia, 1878.

Remarks on origin of iron ores—results of chemical experiment. Relations of hydro-mica slate to limonite.

GROTH, P. Die Mineraliensammlung der Kaiser-Wilhelms-Universitat, Strassburg.

271 pp., Strassburg, 1878.

Lists phlogopite, muscovite and tremolite from Easton and gives brief descriptions of specimens.

HALL, CHARLES E. Catalogue of the Geological Museum, Part I.

Pennsylvania Second Geol. Survey, Report Q, 217 pp., Harrisburg, 1878.

Contains a list of rock specimens collected in the Lehigh Gap and in the slate belt to the south (pp. 155-160).

PRIME, FREDERICK, JR. On the Discovery of Lower Silurian Fossils in Limestone associated with Hydro-mica Slates, and on other points in the Geology of Lehigh and Northampton Counties, Eastern Pennsylvania.

Am. Philos. Soc. Proc., vol. 17, pp. 248-254, Philadelphia, 1878.

Am. Jour. Sci. and Arts, 3d ser., vol. 15, pp. 261-269, New Haven, 1878.

A very good description of the Potsdam (Hardyston) sandstones and quartzites, the hydro-mica slates (Tomstown), the No II or Magnesian limestones (Allentown and Beekmantown), Trenton (Jacksonburg) limestones, and No. III (Martinsburg) slates. Discusses the characteristics and origin of the brown hematite (limonite) iron ores of the region. A few fossils found in Northampton County are described. This paper was first published in Proceedings of the American Philosophical Society under the title "On the Paleozoic Rocks of Lehigh and Northampton Counties, Pennsylvania."

1879

Allen, Charles. Two Hundred Tables of Elevations above tide-level in and around Pennsylvania.

Pennsylvania Second Geol. Survey, Report N, 279 pp., Harrisburg, 1879.

Gives elevations of many points along the following railroads: Delaware & Lackawanna, Lehigh Valley, Lehigh & Susquehanna (Central of New Jersey), Lehigh & Lackawanna (Lehigh & New England), North Pennsylvania (Reading), also levels of various places along the Delaware River.

Clark, Ellis, jr. Shaft Surveying in the Brown Hematite Mines of Northampton County, Pennsylvania.

Am. Inst. Min. Eng. Trans., vol. 7, pp. 139-145. Easton, 1879.

Contains a brief description of some of the ore deposits near Easton.

Clark, Ellis, jr. The Great Blast at Glendon.

Am. Inst. Min. Eng. Trans., vol. 7, pp. 266-293. Easton, 1879.

Brief description of the limestone quarried at Cedar Hill, Palmer Township.

Clauder, H. J. Clauder's Year-Book and Home Almanac for 1879.

Pamphlet, 88 pp., Bethlehem, 1879.

Compilation of interesting information including descriptions of the Bethlehem Water Works, Lehigh Zinc Co., Bethlehem Iron Co., Calypso Island, etc.

Clyde, John C. Genealogies, Necrology and Reminiscences of the Irish Settlement.

449 pp., 3 maps, 1879.

Almost entirely historical and biographical. Maps of interest.

McCreath, Andrew S. Second Report of Progress in the Laboratory of the Survey at Harrisburg.

Pennsylvania Second Geol. Survey, Report MM, 438 pp., Harrisburg, 1879.

Contains many analyses of specimens from Northampton County, including the following materials: Carbonate iron ore (pp. 187-188), two analyses of limonite (brown hematite) ores (p. 218), clay associated with iron ore (p. 268).

Prime, Frederick, jr. Moraines and Surface Drift Deposits of Northampton County, Pa.

Am. Philos. Soc. Proc., vol. 18, pp. 84-85, Philadelphia, 1879.

Glacial moraine from Wind Gap to Portland. Notes on this moraine. Absence of moraine immediately north of the Lehigh River. Drift prominent at West Bethlehem and in West ward at Easton. Moraine in Saucon Valley. No trace of glacial action on South Mountain.

1880

Hall, Charles E. Catalogue of the Geological Museum, Part II.

Pennsylvania Second Geol. Survey, Report QQ, 272 pp., Harrisburg, 1880.

Lists several rock, ore and fossil specimens collected in specific localities in Northampton County (pp. 105-232).

1881

Lesley, J. P. Letter of Transmittal of Report by Charles E. Hall.

Pennsylvania Second Geol. Survey, Report C6, pp. xiii-xvi, Harrisburg, 1881.

Discusses the glacial investigations of H. Carvill Lewis in the vicinity of the Delaware Water Gap.

1882

Chance, H. Martyn. Special Survey of the Lehigh Water Gap in 1875.

Pennsylvania Second Geol. Survey, Report G6, pp. 349-363. Harrisburg, 1882.

The strata exposed in the Lehigh Water Gap are described. A section is given showing the succession and structure of the strata.

CHANCE, H. MARTYN. Special Survey of the Delaware Water Gap in 1874-5.

Pennsylvania Second Geol. Survey, Report G6, pp. 335-348. Harrisburg, 1882.

The succession of strata in the Delaware Water Gap is described. A topographic map (scale: one inch = 800 feet) and several cross sections, one of which is partly within Northampton County, are included. It is said that "some of the lower beds of the conglomerate (Oneida) contain minute pyrite cubes, which in some localities are of large size and auriferous" (p. 347).

FRAZIER, B. W. On Crystals of Axinite from a locality near Bethlehem, Pennsylvania, with some remarks upon the analogies between the crystalline forms of Axinite and Datolite.

Am. Jour. Sci., 3d ser., vol. 24, pp. 439-447, New Haven, 1882.

The crystals were found in a heap of debris about an abandoned iron ore pit about three miles north of Bethlehem. Crystallographic measurements are given.

LEWIS, HENRY CARVILL. New Localities for Gypsum.

Acad. Nat. Sci. of Philadelphia Proc., vol. 34, p. 38, Philadelphia, 1882.

Gypsum in tabular crystals at Smith's quarry at Easton (p. 48).

WHITE, I. C. The Geology of Pike and Monroe Counties.

Pennsylvania Second Geol. Survey, Report G6, pp. 1-333, Harrisburg, 1882.

Contains a number of brief descriptions of portions of Northampton County such as the Delaware Water Gap, Wind Gap, Lehigh Gap, etc. Foot-notes by J. P. L(esley) discuss the origin of the Delaware Water Gap (p. 54) and the Wind Gap (p. 63).

WRIGHT, GEORGE FREDERICK. The Terminal Moraine in Pennsylvania.

Bulletin 14, Essex Institute, pp. 71-73, Salem, Mass., 1882.

Outline of Terminal Moraine—crosses Delaware River at Belvidere, thence crossing Northampton County with a general northwestern course.

1883

LESLEY, J. P., SANDERS, R. N., CHANCE, H. M., PRIME, F. and HALL, C. E. The Geology of Lehigh and Northampton Counties.

Pennsylvania Second Geol. Survey, Report D3, vol. 1, 283 pp., atlas of maps. Harrisburg, 1883.

Contains much geological information on Northampton County including the following: Two analyses of iron ores (p. xiv), geographical description (pp. 1-7), rivers and creeks (pp. 12-18), Kittatinny Mountain (pp. 22-26), slate region (pp. 27-31, 32-35, 83-113, 134-160), drift deposits (pp. xiv, xix), (pp. 37-54), limestone region (pp. 36-37, 54-67, 161-190), syenite (gneiss) region (pp. 67-81, 241-254), iron mines (pp. 190-203), Potsdam (Hardyston) sandstone (pp. 205-214), Durham hills (pp. 254-258).

Atlas contains a colored geological map (scale: 1 inch = 2 miles) of Lehigh and Northampton Counties and part of Berks County, a topographical map of the Durham and Reading Hills (scale: 1 inch = 1,600 feet) between Delaware and Schuylkill Rivers in eighteen sheets, a colored geological and topographic map of southern Northampton County with part of Lehigh County (scale: 1 inch = 1,600 feet) in six sheets showing location of iron mines.

LEWIS, H. CARVILL. The Great Ice Age in Pennsylvania.

Jour. Franklin Inst., vol. 115, pp. 287-307, Philadelphia, 1883.

Describes the glacial phenomena of Pennsylvania. Several references to Northampton County (especially on page 298).

LEWIS, H. CARVILL. The Great Terminal Moraine across Pennsylvania (abstract).

Science, vol. 2, pp. 163-167, map. Cambridge, 1883. Am. Assoc. Adv. Sci. Proc., vol. 31, pp. 389-398, Salem, 1883.

The location and characteristics of the Terminal Moraine across Northampton County from the Delaware River one mile below Belvidere northwestward to Offset Knob where it passed across Blue Mountain are described.

LEWIS, HENRY CARVILL. On the Course of the Great Terminal Moraine through Pennsylvania.

Am. Philos. Soc. Proc., vol. 20, pp. 662-664, map, Philadelphia, 1883.

Hummocks west of Bangor in Northampton County. Striated boulders, clay plain, southwest striæ near Bangor, hence westward out of county.

REICHEL, WILLIAM C. A Red Rose from the Olden Time or A Ramble through the Annals of the Rose Inn and the Barony of Nazareth in the Days of the Province, 1752-1772. Edited by John W. Jordan.

54 pp., Bethlehem, 1883.

Describes an earthquake at Nazareth on November 18, 1755, seventeen days after the great Lisbon earthquake. "In the early morning of the eighteenth of November . . . there was heard in the Barony, with a star-lit sky overhead, a sound as of a rushing wind and of the booming of distant siege guns—when lo! the doors in 'The Rose' swung on their hinges and stood open! Thus it is written in the book of our chronicles—and on its dusty pages it furthermore stands recorded, that the sleepers at the inn on that frosty November morning, rocked in their beds as do mariners in hammocks out at sea" (p. 12). Contains "Historical Map of the Barony of Nazareth in Northampton County, Pennsylvania, comprising its five Moravian Settlements, 1758." Monocacy is spelled "Menagassi."

1884

LESLEY, J. P. Letter of Transmittal of Report on the Terminal Moraine in Pennsylvania and Western New York.

Pennsylvania Second Geol. Survey, Report of Progress Z, pp. v-xlix, Harrisburg, 1884.

Discusses formation of Wind Gap but reaches no decision. Says "river agency is out of the question" (pp. xlii-xliv).

LEWIS, H. C. Report on the Terminal Moraine in Pennsylvania and Western New York.

Pennsylvania Second Geol. Survey, Report Z, 299 pp., plates, maps, sections. Harrisburg, 1884.

Describes the phenomena of the Great Terminal Moraine across Northampton County (pp. 51-65).

LEWIS, H. CARVILL. On supposed Glaciation in Pennsylvania, south of the Terminal Moraine.

Am. Jour. Sci., 3d ser., vol. 28, pp. 276-285, map. New Haven, 1884.

Examines the evidence that has been brought forth by others to indicate an extension of the glacial ice sheet beyond the "Terminal Moraine" passing through Pen Argyl and Belvidere and concludes that it is not valid. Believes that all the so-called glacial till beyond this point in Lehigh and Northampton Counties was laid down by glacial streams. Discusses at some length the various theories proposed for the formation of the Wind Gap. Mentions some phenomena about the Lehigh Gap.

1885

CONDIT, UZAL W. The History of Easton, Pennsylvania, from the Earliest Times to the Present, 1739-1885.

501 pp., illustrated. Easton, 1885.

Contains occasional brief notes on the geography and geology of the section. Descriptions of the great floods of the Lehigh and Delaware Rivers, river navigation, bridges and water supply of Easton.

LESLEY, J. P. A geological hand atlas of the sixty-seven counties of Pennsylvania.

Pennsylvania Second Geol. Survey, Report X, 112 pp., 1885.

The Flint Hill conglomerate which extends from Bucks County into Northampton County is described and assigned to the New Red (p. xxix).

LEWIS, HENRY CARVILL. Marginal Kames.

Acad. Nat. Sci. of Philadelphia Proc., 1885, pp. 157-173, map. Philadelphia, 1885. Abstract—Geological Magazine (series 3), vol. 1, pp. 565-566. London, 1884.

Marginal kames are connected or associated with the Terminal Moraine, yet are of a stratified character. Three occurrences in Northampton County: (1) Mt. Bethel Township, following Jacobus Creek to the Delaware; (2) Upper Mt. Bethel Township at base of Kittatinny Mountain; (3) two little kames south of Ackermanville, Washington Township.

1886

BUCK, WILLIAM J. History of the Indian Walk performed for the Proprietaries of Pennsylvania in 1737; to which is appended a Life of Edward Marshall.

269 pp., 1886.

The most complete account thus far published of the Walking Purchase by which the area contained within Northampton County was obtained from the Indians.

MERRIMAN, MANSFIELD, WELLS, J. H., and ROWLEY, H. W. Map of Bethlehem, South Bethlehem and West Bethlehem compiled from recent surveys by J. H. Wells, C. E., and H. W. Rowley, M. E., under the supervision of Mansfield Merriman, Professor of Civil Engineering in the Lehigh University. Scale: 1 inch = 400 feet. (Map folded in cover).

Published by Edwin G. Close, Manager, Bethlehem, Pa., 1886.

In margin gives dates of several important events in the history of Bethlehem.

PUMPELLY, RAPHAEL, and others. Report on the Mining Industries of the United States.

Vol. 15, Tenth Census, 1025 pp., Washington, 1886.

Some notes on iron mines of Northampton County including magnetite (p. 180), limonite ore analyses (p. 181), carbonate ores (p. 202), and directory (pp. 970-971).

"VON BEN." Skizzen aus dem Leeha-Thale. Eine Sammlung von Nachrichten über die ersten Ansiedlungen der Weissen in dieser Gegend.

260 pp., Allentown, 1886.

Consists of eighty-two sketches published in the "Friedens-Bote," Allentown, between 1880 and 1886, with articles containing geographic descriptions of parts of the Lehigh Valley.

W A Summer Jaunt in 1773.

The Pennsylvania Magazine of History and Biography, vol. 10, pp. 205-213, Philadelphia, 1886.

A manuscript of an unknown writer with annotations by George Morgan Hills. Brief descriptions of Bethlehem, Easton and Nazareth.

1887

BERLIN, A. F. A Game Drive.

The American Antiquarian and Oriental Journal, vol. 9, pp. 311-313, Chicago, 1887.

Describes a system of crumbling walls located one and one-half miles west of Danielsville into which deer were driven by Indians and slaughtered. Says that a "place of encampment of the Indians" was located in the vicinity of Cherryville where many artifacts have been found.

HILL, FRANK A. Lehigh River section continued from Lock 11, southward to the Blue Mountains.

Pennsylvania Second Geol. Survey, Ann. Report, 1886, Part IV, pp. 1372-1385, Harrisburg, 1887.

Gives section of the Oneida conglomerate in the Lehigh Water Gap (pp. 1378-1379).

HOTCHKIN, REV. S. F. A Pocket Gazetteer of Pennsylvania.

174 pp., Philadelphia, Pa., 1887.

Contains a concise description of Northampton County (pp. 129-135).

KNOP, A. Beitrage zur Kentniss-einiger Glieder der Glimmerfamilie Zeitschrift fur Krystallographie und Mineralogie, vol. 12, Leipzig, 1887.

Description of biotite from near Easton, Pennsylvania; analysis (p. 603).

1888

McGEE, W J Three Formations of the Middle Atlantic Slope.

Am. Jour. Sci., 3d ser., vol. 35, pp. 120-143, 328-330, 367-388, 448-466, New Haven, 1888.

Brief descriptions of the Quaternary deposits along the Delaware and Lehigh Rivers in the Lehigh Valley (pp. 379-381, 384, etc.).

1889

DAVIS, WILLIAM MORRIS. The Rivers and Valleys of Pennsylvania.

Nat. Geog. Mag., vol. 1, pp. 183-253, 26 figs., Washington, 1889.

Reprinted in Geographical Essays, pp. 413-485, New York, 1909.

Describes the physiographic history of the Lehigh and Delaware Rivers. Concludes that "the Susquehanna, Schuylkill, Lehigh and Delaware are compound, composite and highly complex rivers, of repeated mature adjustment."

DAVIS, WILLIAM MORRIS, and WOOD, J. WALTER, JR. The Geographic Development of Northern New Jersey.

Boston Soc. Nat. Hist. Proc., vol. 32, pp. 365-423, 14 figs, Boston, 1889.

Contains descriptions of the Delaware River and peneplains which, extending across the Delaware River into Pennsylvania, are represented in Northampton County.

EYERMAN, JOHN. Notes on Geology and Mineralogy.

Acad. Nat. Sci. of Philadelphia, Proc., vol. 41, pp. 32-35, Philadelphia, 1889.

Reports calamine on farm of S. D. Von Stuhen near Dryland, malachite near Bingen and Leithsville, aragonite from Sherrer's quarry along the Delaware above Easton, and quartz from "Court House lot," Easton, and at Flint Hill near Bingen.

EYERMAN, JOHN. The Mineralogy of Pennsylvania, Part I.

54 pp., Easton, 1889.

Describes goethite from iron mines; psilomelane from Bennett mine, one mile south of South Easton and at Wharton Mine, Hellertown; quartz in Easton and at Flint Hill near Leithsville; smoky quartz near Hellertown; actinolite and tremolite from Easton; axinite three miles north of Bethlehem; calamine from Dryland; talc and aragonite from Easton; malachite from Flint Hill, Leithsville.

LESLEY, J. P. Catalogue of the Geological Museum, Part III.

Pennsylvania Second Geol. Survey, Report QQQ, 260 pp., Harrisburg, 1889.

Contains list of glacial drift specimens from Northampton County (p. 19) and a few fossils from Martins Creek (p. 181).

MERRILL, GEORGE P. Among the Pennsylvania Slate Quarries.

Sci. Am. Suppl., vol. 27, no. 681, p. 10874, New York, 1889.

Describes some of the slate quarries especially those of Bangor. Describes quarrying methods, character of slate, etc.

WRIGHT, G. FREDERICK. The Ice Age in North America.

First edition, 622 pp., New York, 1889.

Fifth edition, 763 pp., Oberlin, 1911.

In many places in the volume descriptions of the glacial phenomena of Northampton County are given.

1890

CHAMBERLIN, T. C. Some Additional Evidences bearing on the Interval between the Glacial Epochs.

Geol. Soc. America Bull., vol. 1, pp. 469-480, Washington, 1890.

Several descriptions of the glacial and fluviatile phenomena of the Delaware River Valley in the vicinity of Belvidere by Professor Chamberlin and in discussion by W J McGee and F. J. H. Merrill.

DAVIS, WILLIAM MORRIS. The Rivers of Northern New Jersey with notes on the classification of Rivers in General.

Nat. Geog. Mag., vol. 2 pp. 81-110, 7 figs., Washington, 1890.

Republished in Geographical Essays, pp. 485-513, New York, 1909.

Discusses the physiography of the Delaware River and the peneplains of the region.

HEILPRIN, ANGELO. Principles of Geology.

329 pp., Philadelphia, 1890.

Brief descriptions and illustrations of Delaware Water Gap and glacial phenomena near Bangor.

LESLEY, J. P. A Dictionary of the Fossils of Pennsylvania.

Pennsylvania Second Geol. Survey, Report P4, 3 vols., 1283 pp., Harrisburg, 1889, 1890.

Figures and describes fossils found in Pennsylvania. *Maclurea magna* is described from Northampton County (pp. 369-370).

MERRILL, GEORGE P. Notes on the Serpentinous Rocks of Essex County, New York; from Aqueduct Shaft 26, New York City; and from near Easton, Pennsylvania.

U. S. Nat. Mus. Proc., vol. 12, 1889, pp. 595-600, Washington, 1890.

Describes the alteration of tremolite to serpentine as exhibited in the Old Wolf Quarry, Chestnut Hill, and gives an analysis of tremolite.

1891

CLARKE, F. W., and SCHNEIDER, E. A. On the constitution of certain micas, vermiculites and chlorites.

Am. Jour. Sci., 3d ser., vol. 42, pp. 242-251. New Haven, 1891.

Description of vermiculite at Chestnut Hill, analysis (p. 249).

DAVIS, WILLIAM MORRIS. The Geological Dates of Origin of Certain Topographic Forms on the Atlantic Slope of the United States.

Geol. Soc. America Bull., vol. 2, pp. 545-586, Rochester, 1891.

In several places refers to the development of the peneplains of eastern Pennsylvania. Describes particularly the Cretaceous peneplain how preserved on the top of Blue Mountain, as well as the water gaps and wind gaps that cut through this ridge.

EYERMAN, JOHN. Preliminary notice of some minerals from the serpentine belt, near Easton, Pa.

Acad. Nat. Sci. of Philadelphia Proc., vol. 43, Philadelphia, 1891.

Adds nine new minerals to those already found in the serpentine belt of Easton, Pa.: Hydromagnesite, graphite, topaz, chalcopyrite, pyrite, pseud. of limonite, calcite, muscovite, orthoclase (p. 464).

KIMBALL, JAMES P. Genesis of Iron Ores by Isomorphous and Pseudomorphous Replacement of Limestone, etc.

Am. Geologist, vol. 8, no. 6, pp. 352-376. Minneapolis, 1891.

Observation by Prime at an ore bank near Hellertown, Pennsylvania. Notes alteration of limestone to iron carbonate particle by particle, or "a pseudomorph by replacement" (p. 364).

RAND, THEODORE D. Notes on the genesis and horizons of the serpentines of southeastern Pennsylvania.

Acad. Nat. Sci. of Philadelphia Proc., 1890, pp. 76-123, Philadelphia, 1891.

Presentation of reasons for believing that the steatite and serpentine of Chestnut Hill, north of Easton, have been altered from, or are being altered to, Laurentian gneiss (p. 95).

1892

ANONYMOUS. Pleasant Places on the Reading Railroad. A Directory of Summer Resorts, Hotels, Boarding Houses on the Reading Railroad System.

64 pp., 1892.

Describes advantages and accommodations for summer tourists in Coopersburg, Centre Valley, Bingen, Hellertown and Easton.

DAVIS, WILLIAM MORRIS. On the drainage of the Pennsylvania Appalachians. Boston Soc. Nat. Hist. Proc., vol. 25, pp. 418-420, Boston, 1892.

Believes that "the present courses of the streams have a very specialized relation to the structures that they flow over" but that some may be antecedent and not consequent streams.

EYERMAN, JOHN. Preliminary Notice of Some Minerals from the Serpentine Belt, near Easton, Pennsylvania.

Acad. Nat. Sci. of Philadelphia Proc., 1891. pp. 464-465, Philadelphia, 1892.

Gives brief descriptions of hydromagnesite, graphite, topaz, chalcopyrite, pyrite, limonite and turgite pseudomorphs, calcite, muscovite and orthoclase from localities in Northampton County.

LESLEY, J. P., D'INVILLIERS, E. V., SMITH, A. D. W., and LYMAN, B. S. A Summary Description of the Geology of Pennsylvania.

3 vols., 2638 pp., with atlas of maps, Harrisburg, 1892-1895.

A general summary of information obtained during the progress of the Second Geological Survey of Pennsylvania. Many references to Northampton County, especi-

ally the following: Archean (pp. 74-75, 105-107), South Mountain (p. 144), iron mines (pp. 231-233), Great Valley (pp. 270-286), limestones (pp. 301-308), cement (pp. 337-340), slate (pp. 574-603), Lehigh and Delaware Water Gaps (pp. 633-636, 674-676), arguments against erosion interval at top of slate (Martinsburg) (pp. 710-711), no mineral wealth in North (Blue) Mountain (pp. 711-713). The geological map of Bucks and Montgomery Counties contained in the atlas shows part of Northampton County in the vicinity of Leithsville in which the mapping is partly incorrect according to present views.

MERRIMAN, MANSFIELD. The Strength and Weathering Qualities of Roofing Slates (with discussion by George P. Merrill and Edward H. Williams, Jr.).

Am. Soc. of Civil Eng. Trans., vol. 27, pp. 331-349, 685-688, 3 plates, 5 figures, New York, 1892.

Describes various physical tests made on the soft slates of Northampton County with descriptions of a few quarries.

SALISBURY, R. D. Certain Extra-Morainic Drift Phenomena of New Jersey.

Geol. Soc. America Bull., vol. 3, pp. 173-182, Rochester, 1892.

Describes glacial boulders south of the Lehigh River (p. 179).

SALISBURY, R. D. Preliminary Paper on Drift or Pleistocene Formations of New Jersey.

Annual Report of the State Geologist for the year of 1891, pp. 35-108, Geological Survey of New Jersey, Trenton, 1892.

Reports "glaciated boulders, imbedded in clay which presents the general aspect of till, have been found near South Bethlehem, several hundred feet above the Lehigh River, and at various other points south of the Lehigh" (pp. 106-107).

WRIGHT, G. FREDERICK. Unity of the Glacial Epoch.

Am. Jour. Sci., 3d ser., vol. 44, pp. 351-373, 1892.

Believes that the glacial deposits beyond (southwestward) the Terminal Moraine which he designates the "glacial fringe" is a part of the same ice sheet that formed the moraine. Presents a map of the Delaware River Valley showing the boundary of the fringe at Nazareth.

1893

BARRELL, JOSEPH. A preliminary survey of the South Mountains, with the valleys adjacent, in the vicinity of Lehigh University in respect to glaciation.

Unpublished thesis, 103 pp., maps, plates, 1893. Lehigh University Library.

Valuable on account of descriptions of actual observations. Most important was the finding of "a Medina or Clinton boulder about one foot diameter, decidedly sub-angular buried in soil flush with the surface" almost at crest of South Mountain southeast of Lehigh University campus. Many observations in Saucon Valley.

FOERSTE, AUG. F. New fossil localities in the early Paleozoics of Pennsylvania, New Jersey and Vermont, with remarks on the close similarity of the lithologic features of these Paleozoics.

Am. Jour. Sci., 3d ser., vol. 46, pp. 435-444, 1893.

Brief descriptions of the lithologic and paleontologic features of the Cambrian (Hardyston) sandstones and Cambro-Ordovician limestones along or near the Lehigh River.

HOFF, J. WALLACE. Two Hundred Miles on the Delaware River.

180 pp., Trenton, 1893.

Brief notes on the characteristics of the river.

LAUBACH, CHARLES. Ancient Village Sites along the Delaware River and Durham Creek.

The Archæologist, vol. 1, pp. 61-63. Waterloo, Indiana, 1893.

Describes one locality in Northampton County "located on the western banks of the Delaware River, extending from the northern base of the second spur of the South Mountains, across Frey's Run, a distance of over half a mile."

WILLIAMS, EDWARD H., JR. Glaciation in Pennsylvania.

Science, vol. 21, p. 343, New York, 1893.

Presents evidence to prove that a glacial ice sheet actually passed over South Mountain in the vicinity of Lehigh University.

Wright, G. Frederick. Extra-Morainic Drift in the Susquehanna, Lehigh and Delaware Valleys.

Acad. Nat. Sci. of Philadelphia Proc., Dec. 27, 1892, vol. 44, pp. 469-484, Philadelphia, 1893.

Is inclined to believe "that the lower part of the Lehigh was specially clogged with ice, so as to increase the floods for some distance up toward the gap, but the ice did not pass over South Mountain" during the Ice Age. Discusses evidence of glaciation in the Lehigh Valley beyond the terminal moraine. Does not believe that there was an earlier ice sheet than the one responsible for the Terminal Moraine near Pen Argyl, Northampton County.

1894

Merriman, Mansfield. The Strength and Weathering Qualities of Roofing Slates (with discussion by George P. Merrill, F. Lynwood Garrison and E. H. S. Bailey).

Am. Soc. of Civil Eng. Trans., vol. 32, pp. 529-543, New York, 1894.

Further physical tests on slate including some references to Northampton County slates. A partial chemical analysis is given.

Penrose, R. A. F., jr. The Superficial Alteration of Ore Deposits.

Jour. Geology, vol. II, pp. 288-317, Chicago, 1894.

Brief mention (p. 304) of iron deposits in the Cambrian, Lower Silurian, and Carboniferous rocks of the Appalachian Valley. Many can be shown to be due to superficial replacement of limestones, or even of shales.

Schug, A. School, Road, Borough and Township Map of Northampton County, Pennsylvania, published for A. Schug, of Easton, Pa., 1894, by J. B. Beers & Co., New York.

50"x52". Scale 1 inch = 200 rods.

Locates areas of slate quarries and occasional limestone quarries.

Williams, Edward H., jr. Extramorainic Drift between the Delaware and Schuylkill.

Geol. Soc. America Bull., vol. 5, pp. 281-296, map, Rochester, 1894.

Moraine behind the Lehigh Gap (p. 281). Reference to Report D3, vol. I, 1878, p. 37, re drift on limestone plain. Sketch map showing extramoraine fringe in Lehigh and Northampton Counties. Discussion of river systems, rocks, glacial deposits, Glacial Lake Packer, Packer clay, gravels, drumlins, kames, eskers. Summary of age of till (p. 293). Post glacial interval short. Moraine formed when ice withdrew from the Lehigh—it and extra-morainic deposits contemporaneous and recent.

Williams, Edward H., jr. The Age of the Extra-Moraine Fringe in Eastern Pennsylvania.

Jour. Sci., 3d ser., vol. 47, pp. 33-36, New Haven, 1894.

Presents evidence in support of the view that "as far as Eastern Pennsylvania is concerned, the extra-moraine fringe is of extremely recent origin and, as it antedates the formation of the great moraine, all glacial deposits in this region are of extreme recency."

1895

Lyman, Benjamin Smith. Report on the New Red of Bucks and Montgomery Counties.

Pennsylvania Second Geol. Survey, Summary Final Report, vol. 3, part 2, pp. 2589-2638, Harrisburg, 1895. Accompanying map, 1893.

Flint Hill is described as "formerly supposed to be made up of New Red rocks . . . but it seems rather to consist of the quartzitic early Paleozoic and sandrock called Chikis (Hardyston of present classification) Sandstone, or No. I, which is here more or less reddish and covers the ground with a reddish hard gritty sand similar in color but different in character from the New Red materials" (p. 2602). This idea is no longer held.

Williams, Edward H., jr. Notes on the Southern Ice Limit in Eastern Pennsylvania.

Am. Jour. Sci., 3d ser., vol. 49, pp. 174-185, map. New Haven, 1895.

Describes briefly glacial deposits of the Lehigh Valley and gives map showing their extent.

1896

BARRELL, JOSEPH. The geological history of the Archean Highlands of New Jersey, including their extension in New York and Pennsylvania.

Unpublished Master of Science thesis, 1896. Yale University (?).

"The conclusion was reached by the writer in 1896 that after the completion of the Kittatinny peneplain, a movement of submergence took place which caused the sea to advance far inland beyond the present position of the coastal plain, cutting into and burying the low Kittatinny ridge under sediments." (Am. Jour. Sci., 4th ser., vol. 49, p. 238.)

WALCOTT, CHARLES DOOLITTLE. The Cambrian Rocks of Pennsylvania.

U. S. Geol. Survey Bull. 134, 43 pp., 15 plates. Washington, 1896.

Contains brief descriptions of the Cambrian strata of the Lehigh Valley.

WALTER, EMMA. Does the Delaware Water Gap consist of two river gorges?

Acad. Nat. Sci. of Philadelphia Proc. for 1895, pp. 198-205, Philadelphia, 1896.

Reasons for believing that the Delaware Water Gap was the work of a stream flowing northward, and that the drainage was changed by glaciation. The gravel at West Bethlehem and Easton could be explained by a dam at the gap in that case.

WILLIAMS, EDWARD H., JR. The Mammoth (Coal) bed at Morea, Pa.

Science, new ser., vol. 3, pp. 782-783, New York, 1896.

States that in a small quarry near Siegfried fresh "workable slate is quarried immediately under glacial gravel" which indicates recency of the glacial ice sheet in the region.

WRIGHT, FRED B. The Origin of the Wind Gap.

Am. Geologist, vol. 18, pp. 120-123, map. Minneapolis, 1896.

Presents evidence that the preglacial McMichaels Creek originally crossed Blue Mountain and cut the Wind Gap but the upper portion was robbed by a tributary of Delaware River and diverted to the east.

1897

RAU, ALBERT G. Glacial striæ.

Science, new ser., vol. 6, p. 668, New York, 1897.

Reports unmistakable glacial striæ in Northampton County "at least four miles south of the front of the terminal moraine, as commonly defined."

WILLIAMS, EDWARD H., JR. Greenland glaciers.

Science, new ser., vol. 5, p. 448, New York, 1897.

Phenomena of ice action at Bethlehem cited to prove that "the finding of angular ridges or peaks . . . is . . . no sign of the absence of ice from the locality."

1898

HEILPRIN, ANGELO. The Earth and Its Story.

267 pp., Boston, 1898.

The Delaware Water Gap and the Lehigh Gap are briefly described (p. 58).

MERRIMAN, MANSFIELD. The Slate Regions of Pennsylvania.

Stone for July, 1898. 16 pp., 5 figures. Chicago, 1898.

Short descriptions of the slates and the slate industry of Northampton County.

SALISBURY, ROLLIN D. The Physical Geography of New Jersey.

Vol. IV of the Final Report of the State Geologist, 200 pp., 15 plates, 37 figures, Trenton, 1898.

Discusses features of the Delaware River Valley, Delaware Water Gap, peneplains, etc., that are common to both New Jersey and Pennsylvania.

WILLIAMS, EDWARD H., JR. Notes on Kansan Drift in Pennsylvania.

Am. Philos. Soc. Proc., vol. 37, pp. 84-87, Philadelphia, 1898.

Brief statement that "the Lehigh and its tributaries acquired their present level in pre-Kansan times."

1899

Borhek, Henry T. An attempt to determine the preglacial course of the Manokisy (Monocacy).

Unpublished student thesis, 34 pp., 1 map, 1 chart, 1899, Lehigh University Library.

Presents evidence to show that Monocacy Creek at one time turned to the southwest in the northwest part of Bethlehem, cutting a channel in what is now West Bethlehem, and joined a westward flowing tributary of Lehigh River which then flowed southwestward into Perkiomen Creek.

1900

Anonymous. The Development and Future Prospects of Portland Cement Manufacture in America.

Engineering News and American Railway Journal, vol. 44, pp. 60-62, 1900.

An editorial discussing the history of portland cement.

Hopkins, Thomas C. The Clays of the Great Valley and South Mountain Areas in Pennsylvania.

Pennsylvania State College Annual Report, 1899-1900, Appendix, 45 pp., Harrisburg, 1900.

Describes red brick clay plants of Bethlehem (pp. 30-35). Brief mention of iron ores, cement, slate and soapstone of Northampton County.

Hopkins, T. C. Cambro-Silurian Limonite Ores of Pennsylvania.

Geol. Soc. America Bull., vol. 11, pp. 475-502, pl. 50, Rochester, 1900.

An excellent account of the occurrence, characteristics and origin of the limonite ores of the State, but without especial mention of those of Northampton County. Contains an annotated bibliography.

Peck, Frederick Burritt. On Serpentines and Talcs in the Vicinity of Easton, Pennsylvania (abstract).

Science, new ser., vol. 11, p. 229, New York, 1900.

A brief statement concerning the origin of the tremolite, talc and serpentine of Chestnut Hill.

1901

Hopkins, T. C. Limonite Ores of Pennsylvania.

Mines and Minerals, vol. 21, pp. 97-100, 1900. Scranton, 1901.

Gives list by counties of limonite ore pits, idle and operated, of the Cambro-Ordovician areas of Pennsylvania. Mentions several mines in Northampton County as large producers.

Peck, F. B. Preliminary Notes on the Occurrence of Serpentine and Talc at Easton, Penna.

Annals of the New York Acad. Sci., vol. 13, pp. 419-430, map, New York, 1901.

A concise description of the geology of Chestnut Hill, Easton. Map and several sections.

Rand, Theodore Dehon. Notes on the Geology of Southeastern Pennsylvania.

Acad. Nat. Sci. of Philadelphia Proc., 1900, pp. 160-338, Philadelphia, 1901.

Serpentine altered from enstatite or bronzite (p. 304). All serpentines in southeast Pennsylvania are altered igneous rocks, either pyroxenites or peridotites.

1902

Salisbury, Rollin D. The Glacial Geology of New Jersey.

Final Report of the State Geologist, vol. V, 802 pp., 66 plates, 102 figures, Trenton, 1902.

Many descriptions of the glacial deposits of the Delaware River valley, some of which include features on the Pennsylvania side.

WILLIAMS, EDWARD H., JR. Kansas Glaciation and its Effect on the River System of Northern Pennsylvania.

Wyoming Hist. and Geol. Soc. Proc. and Coll., vol. 7, pp. 21-28, 11 figures, Wilkes-Barre, 1902.

Says the Lehigh originally flowed southward from Allentown through Leipert's Gap and into the Perkiomen "the portion of the stream between Allentown and Easton being a case of piracy on the part of the Delaware, cutting more rapidly than the Lehigh and forcing the low col about Glendon westward till the Lehigh drainage level was reached."

1903

CAMPBELL, MARIUS R. Geographic Development of Northern Pennsylvania and Southern New York.

Geol. Soc. America Bull., vol. 14, pp. 277-296, New York, 1903.

Describes the Harrisburg and Somerville peneplains as developed in Northampton County. Says they are probably of early Tertiary age.

LEVERING, JOSEPH MORTIMER. A History of Bethlehem, Pennsylvania, 1741-1892.

809 pp., 86 plates. Bethlehem, 1903.

Contains much geographic information and descriptions of the industries of the Lehigh Valley.

PECK, FREDERICK B. Basal Conglomerate in Lehigh and Northampton Counties, Pennsylvania.

Geol. Soc. America Bull., vol. 14, pp. 518-521, New York, 1903.

Abstract, Science, new ser., vol. 17, p. 291, New York, 1903; Jour. Geology, vol. 11, pp. 108-109, Chicago, 1903; Eng. and Min. Jour., vol. 75, p. 154, New York, 1903.

A short description of the distribution and characteristics of the Cambrian quartzites, sandstones and conglomerates composing the Hardyston formation as developed in Lehigh and Northampton Counties.

1904

ANONYMOUS. The Thomas Iron Company, 1854-1904.

98 pp., illustrated, New York, 1904.

Contains much historical matter concerning the iron industry of the Lehigh Valley.

DAVIS, WILLIAM MORRIS. Elementary Physical Geography.

401 pp., Boston, 1904.

Brief description of the Delaware Water Gap.

ECKEL, EDWIN C. Cement-rock deposits of the Lehigh District of Pennsylvania and New Jersey.

U. S. Geol. Survey Bull. 225, pp. 448-456, Washington, 1904.

A short description of the geology of the Lehigh cement district with several analyses of cement rock.

EYERMAN, JOHN. Contributions to Mineralogy.

Am. Geologist, vol. 34, pp. 43-48, Minneapolis, 1904.

Gives analyses of orthoclase, tourmaline, biotite, actinolite, asbestos, and serpentine from Easton. Lists the following minerals as occurring there: Graphite; molybdenite (in precious serpentine) rare; chalcopyrite, rare; chalcocite, rare; pyrite; fluorite, rare; galenite, rare; gypsum, rare; quartz; limonite; hematite; calcite; aragonite; hydromagnesite, rare; barite, rare; celestite, rare; strontiano-calcite, rare; malachite; zircon; tremolite; actinolite; asbestos; mountain-leather; pyroxene; coccolite; sahlite; nephrite; serpentine; bowenite; tourmaline; topaz, rare; biotite; phlogopite; talc; orthoclase; prochlorite.

PECK, F. B. The Cement Belt in Lehigh and Northampton Counties of Pennsylvania.

Mines and Minerals, map, 6 figures, vol. 25, pp. 53-57, Scranton, 1904.

Lists and describes the following formations of the Lehigh Valley; Pre-Cambrian crystalline rocks, Cambrian basal conglomerate, Trenton limestone, cement rock, Hudson River slate, Oneida and Medina sandstone. Gives several chemical analyses.

1905

Jordan, John W., Green, Edgar Moore, and Ettinger, George T. Historic Homes and Institutions and Genealogical and Personal Memoirs of the Lehigh Valley, Pennsylvania.

2 vols., 516 pp. and 528 pp., New York, 1905.

Contains biographic sketches of many men who were concerned in the development of the mineral resources of the Lehigh Valley.

Peck, F. B. The Talc Deposits of Phillipsburg, N. J., and Easton, Pa.

Annual Report of the State Geologist for 1904, Geol. Survey of New Jersey, pp. 163-185, 3 plates, map, Trenton, 1905.

Good descriptions of thirteen quarries in Chestnut Hill, Northampton County, where talc or serpentine has been obtained. Several analyses.

1906

Dale, T. Nelson. Slate Deposits and Slate Industry of the United States.

U. S. Geol. Survey Bull. 275, 154 pp., 25 plates, 15 figures, Washington, 1906.

Discusses origin, composition and structure of slate and describes the slate deposits of the county. The individual quarries of Northampton County and the microscopic characteristics of the slate obtained from them are described (pp. 76-81). Contains tests on slates made by Mansfield Merriman.

Fairbanks, Harold Wellman. Practical Physiography.

542 pp., Boston, 1906.

Cut of the Delaware Water Gap.

Tower, Walter S. Regional and Economic Geography of Pennsylvania, Part I, Physiography.

69 pp., Philadelphia, 1906. Reprinted from Bull. Geog. Soc. Philadelphia, vol. 4, January-July, 1906.

In the general descriptions of the physiographic regions of the State, many references are made to the features present in Northampton County.

1907

Chamberlin, Thomas C., and Salisbury, Rollin D.

Geology, vol. I, Geologic Processes, 685 pp., New York, 1906.

Geology, vol. II, Earth History, 692 pp., New York, 1907.

Volumes contain illustrations of the Delaware Water Gap and Kittatinny (Blue) Mountain.

1908

Peck, Frederick B. Geology of the Cement Belt in Lehigh and Northampton Counties, Pa., with brief history of the origin and growth of the industry and a description of the methods of manufacture.

Econ. Geol., vol. 3, pp. 37-76, Lancaster, 1908.

A discussion of the stratigraphy of the region with especial descriptions and analyses of the limestones used in the manufacture of portland cement.

Salisbury, Rollin D. Physiography for High Schools.

531 pp., New York, 1908.

Brief mention of the Delaware Water Gap.

Wherry, Edgar T. Radioactive Minerals Found in Pennsylvania.

Franklin Inst. Jour., vol. 165, pp. 67, 70, 75-78. Philadelphia, 1908.

Tabular list of occurrences of radioactive minerals in Pennsylvania; Northampton County listed.

1909

Chamberlin, Thomas C., and Salisbury, Rollin D. A College Text-Book of Geology.

978 pp., New York, 1909.

View and description of the Delaware Water Gap and vicinity.

GRABAU, A. W. Physical and Faunal Evolution of North America during Ordovicic, Siluric and Early Devonic Time.

Jour. Geology, vol. 17, pp. 209-252, Chicago, 1909.

Mentions the Shawangunk formation thinning southward from 700 feet at the Delaware Water Gap to 400 feet at the Lehigh Gap. Indicates non-marine overlap.

GRABAU, A. W. The Medina and Shawangunk Problems in Pennsylvania.

Science, new ser., vol. 30, p. 415, New York, 1909.

The Shawangunk strata of Blue Mountain are referred to the Salina formation.

LAUBACH, CHARLES. Prehistoric Man in Northern Bucks County.

Bucks County Hist. Soc., vol. 2, pp. 52-57, Easton, 1909.

Describes the finding of stone implements and fireplaces twelve feet below the surface "along Fry's Run, in Williams Township, Northampton County, Pa." Presents evidence "of the presence of an earlier people than the Indian along the valley of the Delaware."

WHERRY, E. T. The Early Paleozoic of the Lehigh Valley District, Pennsylvania.

Science, new ser., vol. 30, p. 416, New York, 1909.

Announces the division of the Cambro-Ordovician limestones of the Lehigh Valley into five formations. Erroneously reports two areas of Shawangunk conglomerate "some twenty miles south of the main exposure in the Blue Ridge."

HALBERSTADT, BAIRD. The Principal Limestone Deposits of Pennsylvania and Their Adaptability to the Manufacture of Portland Cement.

Fifteenth Annual Report of the Pennsylvania Department of Agriculture for 1909, pp. 545-555, Harrisburg, 1910.

Briefly describes the Lehigh cement district.

MERRILL, GEORGE P. Stones for Building and Decoration.

3d ed., 551 pp., 33 plates, 24 figures, New York, 1910. Earlier editions, 1891 and 1897.

Contains brief descriptions of the slates of the Lehigh Valley (pp. 194-195, 400-401, 484-488).

STODDARD, JESSE C., and CALLEN, ALFRED C. Ocher Deposits of Eastern Pennsylvania.

U. S. Geol. Survey Bull. 430, pp. 424-439, 2 figures. Washington, 1910.

Discusses origin of ocher. Describes an umber deposit at Camels Hump.

1911

BLACKWELDER, ELIOT, and BARROWS, HARLAN H. Elements of Geology.

475 pp., New York, 1911.

Delaware Water Gap mentioned.

EYERMAN, JOHN. The Mineralogy of Pennsylvania, Part II.

25 pp., privately published, Easton, 1911.

Gives analyses of diopside (previously labeled sahlite), diopside (previously labeled augite), actinolite, nephrite, serpentine, prochlorite, asbestos, wernerite, biotite and altered biotite (called eastonite), muscovite, and zaratite from Chestnut Hill, Easton. Also analyses of a new clay which is a hydrous aluminum silicate from Simpson Mine, Cedarville, Easton, and turgite from Glendon. Gives descriptions of zircon, topaz, molybdenite and zaratite from Chestnut Hill and allanite and lanthanite from Lower Saucon Township.

EYERMAN, JOHN. Contributions to the Mineralogy of Pennsylvania, V.

7 pp., Easton (no date), 1911(?).

Gives analyses of biotite, serpentine, orthoclase, prochlorite, actinolite and asbestos from Easton. Lists following minerals found at Easton: Graphite; molybdenite; chalcopyrite, rare; chalcocite, rare; pyrite; fluorite, rare; gypsum, rare; quartz; limonite; calcite; aragonite; hydromagnesite, rare; malachite, rare; zircon, rare; tremolite; actinolite; asbestos; mountain-leather; pyroxene; coccolite; sahlite; serpentine; bowenite; topaz; biotite; talc; orthoclase; prochlorite.

HELLER, WILLIAM J. Historic Easton from the Window of a Trolley Car.

181 pp., Easton, 1911.

Contains geographic notes concerning the development of the city and its environs.

MILLER, BENJAMIN L. The Mineral Pigments of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Report 4, 101 pp., 29 plates, 9 figures, Harrisburg, 1911.

Short descriptions of the pre-Cambrian, Cambrian and Ordovician formations of Northampton County. Some ocher, black slate and umber deposits of the county are described.

MILLER, BENJAMIN L. Paint Shales of Pennsylvania.

U. S. Geol. Survey Bull. 470, pp. 485-496, Washington, 1911.

Brief statement of the use of Martinsburg slates of Northampton County for black paint.

PECK, FREDERICK B. Preliminary Report on the Talc and Serpentine of Northampton County and the Portland Cement Materials of the Lehigh District.

Pennsylvania Topog. and Geol. Survey Report 5, 65 pp., 17 plates, 9 figures, Harrisburg, 1911.

Describes the talc and serpentine deposits in Chestnut Hill and other pre-Cambrian rocks of Northampton County. The Cambrian, Ordovician and early Silurian strata of the Lehigh Valley are also described as well as the cement industry of the region.

READING, JOHN, JR. Diary, 1715.

In possession of New Jersey Historical Society. Abstracts published in History of Warren County, New Jersey, by George Wyckoff Cummins (p. 14-17), New York, 1911.

See Reading, John, Jr., 1715.

SCHÖPF, JOHANN DAVID. Travels in the Confederation (1783-1784). Translation of "Reise durch einige der mittlern und sudlichen vereinigten nord amerikanischen staatenunternommen in den Jahren 1783 und 1784."

Two parts, Erlangen, 1788. Translated and edited by Alfred J. Morrison. Two vols., 426 and 324 pp., Philadelphia, 1911.

The author spent some time at Bethlehem and Nazareth and has described the topography, geology of the soils and industries of the inhabitants of these as well as the areas crossed by him in journeying to the Wind Gap. Describes streams, springs, sink holes, rocks, etc. He speaks of the "Leheigh River" as "a soft, clear, pure stream flowing over a rocky bottom." Says the limestone valley was covered with forests consisting "for the greater part of white, red, and black oak" and the slate hills covered with the "bush oak" seldom over three to four feet in height.

ULRICH, E. O. Revision of the Paleozoic Systems.

Geol. Soc. America Bull., vol. 22, pp. 281-680, New York, 1911.

Briefly describes geologic features of the Lehigh Valley in various places (pp. 644-646, 655, 665-666, etc.)

1912

CLARKE, JOHN M., and RUEDEMANN, RUDOLF. The Eurypterida of New York.
New York State Museum, Memoir 14, 628 pp., 88 plates, Albany, 1912.

The following eurypterid forms are described (pp. 417-418) from some thin seams of black shale in the Shawangunk formation in the Delaware Water Gap:

Dolichopterus otisius Clarke.
Eurypterus maria Clarke.
Stylonurus cf. *myops* Clarke.
Hughmilleria shawangunk Clarke.
Pterygotus cf. *globiceps* Clarke & Ruedemann.

COONS, A. T. Slate.

U. S. Geol. Survey, Mineral Resources, 1912, pt. II, pp. 675-692. Washington, 1913.

In addition to statistics there is a general discussion of the economics of the slate industry and methods of working. Frequent reference to the slate of Northampton County.

GLACE, WILLIAM H. A Narrative of Hydraulic Cement Mined in the Lehigh Valley.

16 pp., 3 plates, Catasauqua, 1912.

A sketch of the beginning of cement manufacture in the Lehigh Valley.

HOBBS, WILLIAM HERBERT. Earth Features and Their Meaning.
506 pp., New York, 1912.
Water gaps are described with mention of the Delaware Water Gap as an illustration.

MILLER, BENJAMIN L. Graphite Deposits of Pennsylvania.
Pennsylvania Topog. and Geol. Survey Report 6, 147 pp., 18 plates, Harrisburg, 1912.
A few localities in Northampton County where graphite has been found are briefly described.

SALISBURY, ROLLIN D., BARROWS, HARLAN H., and TOWER, WALTER S. The Elements of Geography.
616 pp., New York, 1912.
Brief mention of the Delaware Water Gap.

WHERRY, EDGAR T. The Triassic of Pennsylvania.
Acad. Nat. Sci. of Philadelphia Proc., vol. 64, p. 156, Philadelphia, May, 1912.
Brief abstract of article later published in full in Proc. of the Acad. Nat. Sci. of Philadelphia, vol. 65, pp. 114-125, Philadelphia, March 1913.

1913

BARRELL, JOSEPH. Piedmont terraces of the northern Appalachian and their origin.
Abstract, Geol. Soc. Am. Bull., vol. 24, pp. 688-690, 1913.
Post-Jurassic history of the northern Appalachians.
Abstract and discussion, Geol. Soc. Am. Bull., vol. 24, pp. 690-696, 1913.
In these two papers Barrell suggested the formation of the terraces (peneplanes) of the Appalachians by marine planation instead of fluvial erosion.

BROWN, AMOS P., and EHRENFELD, FREDERICK. Minerals of Pennsylvania.
Topog. and Geol. Survey of Pennsylvania Report 9, 160 pp., 10 plates, 1 figure, Harrisburg, 1913.
Describes the important minerals and rocks of Pennsylvania and gives the principal localities where they occur. Many localities in Northampton County are cited.

DALE, T. NELSON. The Commercial Qualities of the Slates of the United States, and Their Localities.
U. S. Geol. Survey, Mineral Resources, 1912, Part 2, pp. 693-707, Washington, 1913.
Describes the distribution and characteristics of the "soft vein" and "hard vein" slates of Lehigh and Northampton Counties with brief descriptions of some quarries.

ECKEL, EDWIN C. Portland Cement Materials and Industry in the United States; with contributions by E. F. Burchard and others.
U. S. Geol. Survey Bull. 522, 401 pp., maps, Washington, 1913.
Contains a short chapter on the cement materials and cement industry of the Lehigh District (pp. 310-322) with a generalized map of the region.

FREAR, WILLIAM, and ERB, E. S. The Lime Resources of Pennsylvania.
Annual Report of Pennsylvania State College for 1911-1912, pp. 272-440, Harrisburg, 1913.
Brief description of the Northampton County limestones (p. 318).

FREAR, WILLIAM. Pennsylvania Limestone and Lime Supplies.
Pennsylvania State College Agr. Exp. Sta. Bull. 127, pp. 71-106, State College, 1913.
Contains three analyses of Northampton County limestones (p. 94).

GRABAU, AMADEUS W. Early Paleozoic Delta Deposits of North America.
Geol. Soc. America Bull., vol. 24, pp. 399-528, New York, 1913.
Discusses the origin and correlation of various Paleozoic formations represented in Northampton County, particularly the Martinsburg and Shawangunk and mentions specifically a few localities within the county.

HICE, RICHARD R. Mineral Production of Pennsylvania for 1911.

Topog. and Geol. Survey of Pennsylvania Report 8, 138 pp., 51 pp., 84 pp., Harrisburg, 1913.

Statistics of mineral production with lists of producers.

WHERRY, EDGAR T. North Border Relations of the Triassic in Pennsylvania.

Acad. Nat. Sci. of Philadelphia Proc., vol. 65, pp. 114-125, map, Philadelphia, 1913.

Describes the conglomerates occurring in the north border of the Triassic in the extreme south corner of Northampton County. Thinks that the cobbles of the conglomerate were transported by floating ice in streams coming from the Appalachian Mountains to the north. Abstracts of article previously published in Geo. Soc. Amer. Bull., vol. 23, pp. 745, 1911, and in Acad. Nat. Sci. of Philadelphia Proc., vol. 64, p. 156, 1912.

1914

BOWMAN, ISAIAH. Forest Physiography.

759 pp., New York, 1914.

Brief description of the formation of the Delaware Water Gap.

CHAMBERLIN, THOMAS C., and SALISBURY, ROLLIN D. Introductory Geology.

708 pp., New York, 1914.

View of Kittatinny Mountain and the Delaware Water Gap.

DALE, T. NELSON, and others. Slate in the United States.

U. S. Geol. Survey Bull. 586, 220 pp., 26 plates, 18 figures, Washington, 1914.

Discusses origin, composition, texture, structure, and economic geology of slate. Several Northampton County quarries are described (pp. 96-104).

HICE, RICHARD R. Mineral Production of Pennsylvania for 1912.

Topog. and Geol. Survey of Pennsylvania Biennial Report for the two years ending June 1, 1914, pp. 79-232, Harrisburg, 1914.

Statistics of the mineral production of the county, with short descriptions of each product.

SALISBURY, S. H., JR., and BECK, GEORGE C. A Study of the Dolomitic Limestones of the Allentown Quadrangle.

Jour. Indus. and Chem. Eng., vol. 6, no. 10, pp. 837-851, New York, 1914.

A chemical investigation of some dolomitic limestones of the Lehigh Valley. Many analyses and discussions of origin of the dolomites.

TARR, RALPH STOCKMAN (published under editorial direction of Lawrence Martin). College Physiography.

837 pp., New York, 1914.

Cut and brief description of the Delaware Water Gap.

WHERRY, EDGAR T. Notes on Wolframite, Beraunite and Axinite.

U. S. Nat. Mus. Proc., vol. 47, pp. 501-511, Washington, 1914.

Describes a new occurrence of beraunite associated with psilomelane and cacoxenite from an old iron mine about one mile southeast of Hellertown. Gives seven chemical analyses.

1915

HICE, RICHARD R. Mineral Production of Pennsylvania for the Year 1913.

Topog. and Geol. Survey of Pennsylvania Report 11, 108 pp., Harrisburg, 1915.

Statistics of the mineral production of the county with short descriptions of each product.

SHAW, CHARLES F., MCKEE, J. M., and ROSS, W. G. Reconnaissance Soil Survey of Southeastern Pennsylvania.

U. S. Dept. Agr., Field Operations of the Bureau of Soils, 1912, pp. 247-340, map, Washington, 1915.

Describes the soil types and their adaptabilities in nineteen counties of southeastern part of Pennsylvania, including Northampton County. Map shows distribution of the various soils. The history and development of the region is described. Many references to the geological features.

WHERRY, EDGAR T. A Peculiar Oolite from Bethlehem, Pennsylvania.
U. S. Nat. Mus. Proc., vol. 49, pp. 153-156, 2 plates, Washington, 1915.
Describes a peculiar oolite just north of Bethlehem, in which many spherules have the lower portion dark and the upper portion white.

1916

CLELAND, HERDMAN FITZGERALD. Geology, Physical and Historical.
718 pp., New York, 1916.
Mentions the Delaware Water Gap.

SCHUCHERT, CHARLES. Silurian Formations of Southeastern New York, New Jersey and Pennsylvania.
Geol. Soc. America Bull., vol. 27, pp. 531-554, New York, 1916.
Discusses the correlation of the Shawangunk formation and concludes that it is of Medina-Clinton-Niagaran age. The sections at Delaware Water Gap and Lehigh Gap are described.

STOSE, GEORGE W. The Delaware Water Gap.
Printed on back of Delaware Water Gap topographic map, U. S. Geol. Survey, Washington, 1916 and 1922.
A generalized description of the geologic and physiographic features of the Delaware Water Gap quadrangle.

WATER SUPPLY COMMISSION OF PENNSYLVANIA. Water Resources Inventory Report.
Part V, Precipitation, 205 pp., 1916.
Gives precipitation data for Bethlehem, Easton and Nazaretb.
Part IX, Navigation, 105 pp., 1916.
Information concerning the Lehigh Coal and Navigation Co. and tbe Delaware River.

1917

ANDERSON, JOHN A. Navigation on the Delaware and Lehigh Rivers.
Bucks County Hist. Soc., vol. 4, pp. 282-312, Easton, 1917.
Describes the utilization of the Lehigh and Delaware Rivers before the advent of the railroad.

OERTER, ALBERT L. Tile Stoves of the Moravians at Bethlehem, Pa.
Bucks County Hist. Soc., vol. 4, pp. 479-481, Easton, 1917.
Brief description of the making of pottery, tile and clay pipes of local clay at Bethlehem between 1743 and 1793.

RAPP, R. FRANCIS. Lehigh and Delaware Division Canal Notes.
Bucks County Hist. Soc., vol. 4, pp. 600-606, Easton, 1917.
Some interesting facts concerning navigation on the Lebigh Canal and Lehigh River and descriptions of floods of the Lehigh River.

SCHRADER, FRANK C., STONE, RALPH W., and SANFORD, SAMUEL. Useful Minerals of the United States (A Revision of Bulletin 585 (250 pp.) Washington, 1914).
U. S. Geol. Survey Bull. 624, 412 pp., Washington, 1917.
Lists following minerals and rocks from Northampton County: Allanite, asbestos, cement material, cuprite, fluorspar, marble, mineral paint, psilomelane, molding sand, serpentine, black shale, slate, talc, umber, wad, wavellite.

WATER SUPPLY COMMISSION OF PENNSYLVANIA. Water Resources Inventory Report.
Part III, Gazetteer of Streams, 657 pp., Harrisburg, 1917.
Gives natural and artificial features of the following streams. Delaware and Lehigh rivers, and Martins, Bushkill, Hokendauqua, Monocacy, Saucon and Durham Creeks.
Part VII, Water Power, 109 pp., Harrisburg, 1917.
Describes dams and water power of the Lehigh Coal & Navigation Co.
Part VIII, Floods, 108 pp., Harrisburg, 1917.
Describes floods of tbe Delaware and Lehigh Rivers.

WATSON, THOMAS L. Weathering of Allanite.

Geol. Soc. America Bull., vol. 28, pp. 463-500, New York, 1917.

Describes the occurrence of allanite in pegmatites one mile south of Redington and on South Mountain south of Bethlehem.

WILLIAMS, EDWARD HIGGINSON, JR. Pennsylvania glaciation; first phase.

101 pp., map, 56 figures, Woodstock, Vermont, 1917.

Contains many descriptions of the glacial deposits of Northampton County.

1918

SHAW, EUGENE WESLEY. Ages of Peneplains of the Appalachian Province.

Geol. Soc. America Bull., vol. 29, pp. 579-586, New York, 1918.

Presents evidence to show that the oldest peneplains now represented in the Appalachian region are no older than Tertiary and perhaps Middle Tertiary.

WHERRY, EDGAR T. Pre-Cambrian Sedimentary Rocks in the Highlands of Eastern Pennsylvania.

Geol. Soc. America Bull., vol. 29, pp. 375-392, New York, 1918. (Abstract in vol. 28, p. 156, 1917.)

Describes crystalline limestone, quartz-mica schist, graphite-bearing quartzite, and basic (amphibolite) gneiss of pre-Cambrian age in Northampton County and argues for their sedimentary origin. Article illustrated by photomicrographs and other figures.

WHERRY, EDGAR T. Notes on Mimetite, Thaumasite and Wavellite.

U. S. Nat. Mus. Proc., vol. 54, pp. 373-381, plate, Washington, 1918.

Gives crystallographic measurements and chemical analysis of wavellite from abandoned iron mine one mile southeast of Hellertown.

1919

POSNJAK, EUGEN, and MERWIN, H. E. Hydrated ferric oxides.

Am. Jour. Sci., 4th ser., vol. 47, pp. 311-348, New Haven, 1919.

Discusses the relations and characteristics of the different iron oxides. Gives two analyses and descriptions of specimens of lepidocrocite from Easton.

SALISBURY, ROLLIN D. Physiography.

3d ed., 676 pp., New York, 1919.

Brief mention of the Delaware Water Gap. Also mentioned in first edition, 359 pp., New York, 1910.

1920

BARRELL, JOSEPH. The Piedmont Terraces of the Northern Appalachians.

Am. Jour. Sci., 4th ser., vol. 49, pp. 227-258, 327-362, 407-428, 6 plates, 18 figures, New Haven, 1920. Arranged and edited by H. H. Robinson from notes and unfinished manuscripts left by Prof. Barrell.

Describes peneplains, wind gaps and water gaps of eastern Pennsylvania, with many specific references to these phenomena in Northampton County.

HELLER, WILLIAM J. History of Northampton County and the Grand Valley of the Lehigh.

Two parts bound in 3 vols., General History 536 pp. and Biography 655 pp., American Historical Society, New York, 1920.

Has separate chapters on Iron and Kindred Industries (pp. 269-277), Slate Industry (pp. 279-287), and Cement Industry (pp. 283-287). In the descriptions of the boroughs and townships, many mines, quarries, etc., are described.

WATER SUPPLY COMMISSION OF PENNSYLVANIA. Water Resources Inventory Report.

Part VI, Water Supply, 1,387 pp., 1920.

Describes water supplies of Bath, Bethlehem, Catasauqua, Cementon, Coplay, East Catasauqua, Egypt, Fullerton, Hokendauqua, West Catasauqua, West Coplay, Hellertown, Nazareth, Pen Argyl, West Pen Argyl, Wind Gap, Lower Saucon Township (part), and Walnutport.

WILLIAMS, EDWARD H., JR. The Deep Kansan Pondings in Pennsylvania and the Deposits Therein.

Am. Philos. Soc. Proc., vol. 19, pp. 49-84, Philadelphia, 1920.

Brief mention of glacial phenomena in the Lehigh Valley.

1921

Bascom, F. Cycles of Erosion in the Piedmont Province of Pennsylvania. Jour. Geol., vol. 29, pp. 540-559, Chicago, 1921.

Describes five peneplains in Pennsylvania all of which should be represented in Northampton County although only a few localities within the county are specifically mentioned. Peneplains described are Kittatinny (1800'-1100'), Schooley (1300'-900'), Honeybrook (860'-700'), Harrisburg (800'-500'), and Early Brandywine (500'-390').

Fuller, Merton O. Test of Physical and Electrical Properties of Slate. Fritz Engineering Laboratory, Lehigh University, 34 pp., figures, tables, Bethlehem, 1921.

Describes the results of various physical tests made on slate from Pen Argyl, Northampton County.

Peters, Richard, Jr. Two Centuries of Iron Smelting in Pennsylvania. 83 pp., illustrated, Philadelphia, 1921.

Contains considerable information concerning the early iron industry in the Lehigh Valley.

1922

Bowles, Oliver. The Technology of Slate. U. S. Bur. Mines Bull. 218, 132 pp., 6 plates, 41 figures, Washington, 1922.

The bulletin deals particularly with the technology of the slate industry but contains numerous descriptions of geologic features observed in quarries in Northampton County.

Gordon, Samuel G. The Mineralogy of Pennsylvania. Acad. Nat. Sci. of Philadelphia Sp. Pub. No. 1, 255 pp., Philadelphia, 1922.

Describes all the minerals known to occur in the State and gives list of minerals and specific localities for each county with literature references. Cites many minerals from Northampton County.

Kelsey, Rayner Wickersham. Casenove Journal, 1794. A record of the journey of Theophile Cazenove through New Jersey and Pennsylvania. Translated from the French manuscript in Library of Congress, 103 pp., 5 plates, Haverford, 1922.

Traveled through the country stopping at Easton, Nazareth and Bethlehem. Brief mention of physical features. He states that the Wind Gap was formerly the bed of the Delaware.

Wyer, Samuel S. The Smithsonian Institution's Study of Natural Resources Applied to Pennsylvania's Resources. 150 pp., Washington, 1922.

Interesting generalizations concerning Pennsylvania's resources. Discussions of limestones, lime and cement apply to Northampton County.

1924

Bowles, Oliver. Technical Progress in Slate Mining. Eng. and Min. Jour.-Press, vol. 117, pp. 605-609, New York, 1924.

Describes new methods of quarrying in some of the slate quarries of Northampton County.

Brown, Thomas Clacher. Origin of Oolites and the Oolitic Texture in Rocks. Geol. Soc. America Bull., vol. 35, pp. 745-780, plates 26-28, New York, 1924.

Figures oolites from Bethlehem in which each spherule is half-light and half-dark.

Fox, R. L., and Grosshart, L. J. H. Water Supply of the Lehigh Valley. Engineers Club of the Lehigh Valley Proc., Spring issue, 6 pp., 1924.

A discussion of the water situation in the Lehigh Valley with a brief statement concerning the source of supply of each municipality.

Knopf, Eleanora B. Correlation of residual erosion surfaces in the eastern Appalachian Highlands. Geol. Soc. Am. Bull., vol. 35, pp. 633-668, 1924.

Identifies and correlates remnants of ten erosion surfaces in Pennsylvania of which seven are represented in Northampton County. They are, in order of decreasing

elevation and decreasing age—Kittatinny (1,660'). Schooley (1,400'-1,300'). Mine Ridge (1,100'-1,000'), Honeybrook (900'-840'), Sunbury (700'-600'), Harrisburg (Bryn Mawr ?) (560'-500'). Lancaster (Brandywine (?), Somerville) (440'-400'). Present maps of different periods showing development of present drainage.

Lesley, Robert W. History of the Portland Cement Industry in the United States.

330 pp., plates and figures, Chicago, 1924.

An excellent account of the history of the portland cement industry in the Lehigh District of Lehigh and Northampton Counties.

Miller, Benjamin LeRoy. Lead and Zinc Ores of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 5, 89 pp., Harrisburg, 1924.

Mentions the occurrence of galena, calamine, and sphalerite in Northampton County.

Moore, E. S., and Taylor, T. G. The Silica Refractories of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 3, 99 pp., Harrisburg, 1924.

In the discussion of the silica refractories of the State, brief mention is made of the siliceous sediments of Blue Mountain.

1925

Ashley, George H. Silurian Stratigraphy at Lehigh Gap, Pennsylvania.

Topog. and Geol. Survey of Pennsylvania Bull. 88, 6 pp., Harrisburg, 1925.

Gives measurements at Lehigh Gap of 250 feet of Tuscarora sandstone, 555 feet of Juniata sandstone and shale and 464 feet of Oswego sandstone.

Behre, Charles H., Jr. Taconic Folding in the Martinsburg Shales (abstract).

Geol. Soc. America Bull., vol. 36, pp. 157-158, New York, 1925.

Evidence presented to show that the Taconic disturbance was in eastern Pennsylvania "almost if not quite as violent as the Appalachian revolution."

Dake, C. L., and Brown, J. S. Interpretation of Topographic and Geologic Maps.

355 pp., New York, 1925.

Describes the formation of water gaps and uses Delaware Water Gap as an example.

Espenshade, A. Howry. Pennsylvania Place Names.

375 pp., State College, 1925.

Contains considerable geographic information concerning places in Northampton County.

Miller, Benjamin LeRoy. Limestones of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 7, 368 pp., 15 plates, figures, Harrisburg, 1925.

Contains data concerning the limestones of Northampton County and their adaptabilities.

Miller, Benjamin LeRoy. Mineral Resources of the Allentown Quadrangle.

Pennsylvania Topog. and Geol. Survey Atlas 206, 195 pp., map, illustrations, Harrisburg, 1925.

A description of the mineral resources of that portion of Northampton County embraced within the Allentown quadrangle.

Miller, Benjamin L. Taconic Folding in Pennsylvania (abstract).

Geol. Soc. America Bull., vol. 36, p. 157, New York, 1925.

Attention called to a marked unconformity at the base of the Shawangunk.

Miller, William J. An Introduction to Geology, Part II, An Introduction to Historical Geology.

399 pp., New York, 1925.

Brief account of the formation of the Delaware Water Gap.

1926

BEHRE, CHARLES H., JR. Observations on Structures in the Slates of Northampton County, Pennsylvania.

Jour. Geology, vol. 34, pp. 481-506, Chicago, 1926.

A description of the secondary structures observed in the Martinsburg slates of Northampton County, Pennsylvania.

LAURY, PRESTON ALEPH, and others. The Scotch Irish of Northampton County, Pennsylvania.

Northampton County Hist. and Gen. Soc., vol. 1, 594 pp., illustrations, maps, Easton, 1926.

Almost exclusively historical and biographical. A few geographic notes.

MEADE, RICHARD K. Portland Cement: Its composition, raw materials, manufacture, testing and analysis.

3d ed., 707 pp., Easton, 1926. Previous editions published in 1906 and 1911.

Contains descriptions of the raw materials and the processes of manufacture of portland cement in the Lehigh District.

MILLER, B. L. Taconic Folding in Pennsylvania.

Geol. Soc. of America Bull., vol. 37, pp. 497-512, New York, 1926.

Evidence presented to prove period of orogenic activity at close of Martinsburg deposition and pronounced unconformity between Martinsburg and Shawangunk formations.

1927

BEHRE, CHARLES H., JR. Slate in Northampton County, Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 9, 308 pp., Harrisburg, 1927.

An exhaustive account of the stratigraphy, structure and economic features of the slate region of Northampton County.

SCHUCHERT, CHARLES, and LEVENE, CLARA M. The Earth and Its Rhythms 410 pp., New York, 1927.

Contains a cut of the Delaware Water Gap accompanied by a brief description.

STOSE, GEORGE W., and JONAS, ANNA I. Ordovician shale and associated lava in southeastern Pennsylvania.

Geol. Soc. Am. Bull., vol. 38, pp. 505-536, 1927.

Discusses the stratigraphic relations and fossils of the Leesport cement rock at Nazareth and the lenticular limestone areas north of Seemsville.

STOSE, GEORGE W. Possible Post-Cretaceous Faulting in the Appalachians.

Geol. Soc. Am. Bull., vol. 38, pp. 493-504, 1927.

Suggests the correlation of the Kittatinny and Schooley peneplanes. The greater elevation of the peneplane on Kittatinny Mountain as compared with the one developed on Scott and Schooley Mountains (N. J.) is explained by normal faulting in post-Cretaceous and pre-Harrisburg peneplanation time.

1928

BEHRE, CHARLES H., JR. Geologic Factors in the Development of the Eastern Pennsylvania Slate Belt.

Amer. Inst. Min. and Met. Eng. Trans., vol. 76, pp. 393-412, N. Y., 1928.

Describes particularly the structural features of the Martinsburg slates of the Lehigh slate district.

DONEHOO, GEORGE P. A History of the Indian Villages and Place Names in Pennsylvania.

290 pp., Harrisburg, 1928.

Considerable geographic information concerning Northampton County. Topics discussed include Forks of the Delaware, Delaware Water Gap, the Delaware Indians, Lehigh River, Hokendauqua, Monocacy, Nolamattink, Saucon, Walking Purchase and Welagamika.

ECKEL, EDWIN C. Cements, Limes and Plasters.

3d ed., 699 pp., 161 figures, New York, 1928. Previous editions published in 1905 and 1922.

Contains many descriptions of the cement industry of the Lehigh Valley.

FENNEMAN, NEVIN M. Physiographic Divisions of the United States, 3d ed.

Annals of the Assoc. of Am. Geographers, vol. 18, pp. 261-353, 1928.

Map shows the different physiographic divisions represented in eastern Pennsylvania, with brief descriptions in the text.

WILLARD, BRADFORD. The Age and Origin of the Shawangunk Formation.

Jour. Paleont., vol. 1, no. 4, pp. 255-258, 1928.

Contains description of stratigraphy in Delaware and Lehigh water gaps.

1929

BRANDT, FRANCIS BURKE. The Majestic Delaware: The Nation's Foremost Historic River.

192 pp., 178 illustrations, Philadelphia, 1929.

The Delaware Water Gap and the Delaware River throughout are described.

ERBE, HELLMUTH. Bethlehem, Pa. Eine kommunistische Herrnhuter Kolonie des 18. Jahrhunderts.

191 pp., 8 plates, Stuttgart, 1929, Lehigh Univ. Library.

Contains considerable geographic information and copies of early maps. Excellent bibliography.

KNOPF, ELEANORA BLISS, and JONAS, ANNA I. Geology of the McCalls Ferry-Quarryville District, Pennsylvania.

U. S. Geol. Survey Bull. 799, 156 pp., Washington, 1929.

Discusses the peneplains and physiographic development of southeastern Pennsylvania including Northampton County. Presents generalized maps.

PIRSSON, LOUIS V., and SCHUCHERT, CHARLES. A Textbook of Geology, Part I, Physical Geology.

488 pp., New York, 1929.

Wind Gap at Pen Argyl and the Delaware Water Gap are briefly described. A cut of each is given.

WARD, FREEMAN. A Wisconsin Ice Tongue in the Delaware Valley.

Am. Jour. Sci., 5th ser., vol. 18, pp. 446-448, 1929.

Describes a deposit of Wisconsin till in the Delaware River Valley, four and one-half miles below Easton and "an older (Illinois or Jersey) glaciation is believed to reach Riegelsville, some 20 miles along the valley south of the Wisconsin terminal moraine."

WILLARD, BRADFORD. Stratigraphic Aspect of Taconic Disturbance.

Pan-American Geologist, vol. 51, pp. 93-96, Des Moines, 1929.

A summary of events during late Ordovician and early Silurian as interpreted from the geologic sections at Delaware Water Gap and Lehigh Gap.

1930

PIRSSON, LOUIS V., and LONGWELL, CHESTER R. Outlines of Physical Geology.

376 pp., New York, 1930.

Formation of water gaps described with cut of Lehigh Water Gap as an example. Gives an illustration of the Wind Gap near Pen Argyl.

SHAW, JOSEPH B. The Ceramic Industries of Pennsylvania.

School of Min. Ind., Pennsylvania State College, Bull. 7, 206 pp., State College, 1930.

A general account of the ceramic industries of the State with a list of producers. Contains some facts regarding the clay, lime, brick and cement plants of Northampton County.

STONE, RALPH W. Pennsylvania Caves.

Pennsylvania Topog. and Geol. Survey Bull. G 3, 63 pp., 34 figures, Harrisburg, 1930.

A discussion of cave formation with descriptions of four caves in Northampton County.

STOSE, GEORGE W. Unconformity at the Base of the Silurian in Southeastern Pennsylvania.

Geol. Soc. America Bull., vol. 41, pp. 629-658, abstract, p. 88, New York, 1930.

States that the Martinsburg shale is made up of two members and the Medina unconformably overlies the lower member.

VER STEEG, KARL. Windgaps and Watergaps of the Northern Appalachians, Their Characteristics and Significance.

Annals of New York Acad. Sci., vol. 32, pp. 87-220, 172 figures, New York, 1930.

An elaborate discussion of the gaps in Blue Mountain and other similar ridges. The paper is discussed by W. O. Hickok in Am. Jour. Sci., 5th ser., vol. 25, pp. 101-122, 1933, and a reply by Ver Steeg is contained in same periodical, 5th ser., vol. 26, pp. 507-511, 1933. Is again discussed in same journal, vol. 27, pp. 410-416, 1934, by Howard A. Meyerhoff and Elizabeth W. Olmsted. Ver Steeg continues discussion in vol. 30, pp. 98-105, 1935 and reply is given by Meyerhoff and Olmsted in vol. 31, pp. 391-393, 1936.

WARD, FREEMAN. The Role of Solution in Peneplanation.

Jour. Geology, vol. 38, pp. 262-270, Chicago, 1930.

Attributes the development of the so-called "Somerville peneplain" to the work of solution rather than ordinary surface erosion.

WOOLF, D. O. The Results of Physical Tests of Road-Building Rock.

U. S. Dept. Agr. Misc. Pub. 76, 148 pp., Washington, 1930.

Gives physical tests of fourteen samples of limestone, dolomite, slate and "diorite" from Northampton County.

1931

ASHLEY, GEORGE H. A Syllabus of Pennsylvania Geology and Mineral Resources.

Pennsylvania Topog. and Geol. Survey Bull. G 1, 160 pp., 2 plates, 118 figures, Harrisburg, 1931.

Contains many brief descriptions of the geology and mineral products of Northampton County.

HOBBS, WILLIAM HERBERT. Earth Features and Their Meaning.

517 pp., New York, 1931.

Brief description of the Delaware Water Gap.

JOHNSON, DOUGLAS. Stream Sculpture on the Atlantic Slope: A Study in the Evolution of Appalachian Rivers.

142 pp., 21 figures, New York, 1931.

Offers a new explanation for the development of the Lehigh and Delaware rivers and the Wind Gap. Elaborates a theory advanced by Barrell in 1896 (which see).

LAHEE, FREDERIC H. Field Geology.

3d ed., 789 pp., New York, 1931.

Cut and brief description of the Delaware Water Gap. Also mentioned in earlier edition, 508 pp., New York, 1916.

STOSE, GEORGE W., and LJUNGSTEDT, O. A. Geologic Map of Pennsylvania.

Pennsylvania Topog. and Geol. Survey, scale: 1 inch = 6 miles, Harrisburg, 1931.

Shows generalized geologic formation lines of Northampton County.

SWARTZ, CHARLES K., and SWARTZ, FRANK M. Early Silurian Formations of Southeastern Pennsylvania.

Geol. Soc. America Bull., vol. 42, pp. 621-662, New York, 1931.

Gives detailed geologic sections through Lehigh Gap and Delaware Water Gap with some notes on the intervening area.

VER STEEG, KARL. Warping of Appalachian Peneplains.

Jour. Geol., vol. 39, pp. 386-392, Chicago, 1931.

Concludes that "the uplift of the Harrisburg surface appears to have been, in eastern Pennsylvania, a vertical one unaccompanied by widespread warping."

1932

BEHRE, C. H., JR. The Bangor-Pen Argyl Slate Region, Pennsylvania.
XVI International Geological Congress, Guidebook 8, pp. 15-30, 2 plates, 9 figures, Washington, 1932.
A concise account of the stratigraphy, structure, petrology and economic geology.

BROWN, COL. EARL I. Report on Lehigh River, Pa., Covering Navigation, Flood Control, Power Development, and Irrigation.
49 pp., 18 maps and profiles, U. S. War Dept., Washington, 1932.
Contains a mass of useful information concerning the Lehigh River.

BURKHARDT, F. A. Tracks, Trails and Traces of Lehigh Valley Regions.
Lehigh County Hist. Soc. Ann. Proc., Allentown, 1932, pp. 3-17.
Says there was a large Shawnee village where Easton now is located.

FACKENTHAL, B. F., JR. Improving Navigation On the Delaware River With Some Account of Its Ferries, Bridges, Canals and Floods.
Bucks County Hist. Soc., vol. 6, pp. 103-230, Allentown, 1932.
Descriptions of the Delaware and Lehigh Rivers and the Lehigh Canal.

JOHNSON, DOUGLAS, BASCOM, FLORENCE, and SHARP, HENRY S. Geomorphology of the Central Appalachians.
XVI International Geological Congress, Guidebook 7, 50 pp., 2 plates, 28 figures, Washington, 1932.
Describes the physiographic divisions represented in Northampton County. Includes a geologic section at Delaware Water Gap.

KESSLER, D. W., and SLIGH, W. H. Physical Properties and Weathering Characteristics of Slate.
U. S. Bur. Standards Jour. of Research, vol. 9, pp. 377-411, 8 figures, Washington, 1932. Reprinted as Bur. Standards Research Paper 477.
Various physical properties of 45 specimens of slate from different slate companies in Northampton County were determined and general conclusions stated.

LONGWELL, CHESTER R., KNOPF, ADOLPH, and FLINT, RICHARD R. A Textbook of Geology, Part I, Physical Geology.
514 pp., New York, 1932.
Cut and brief description of the Lehigh Water Gap. Profile of the Lehigh River.

MATHER, KIRTLEY F. Old Mother Earth.
177 pp., Cambridge, 1932.
Brief description of the origin of the Delaware Water Gap.

MCLAUGHLIN, DEAN B. The Thickness of the Newark Series in Pennsylvania and the Age of the Border Conglomerate.
Michigan Acad. Sci., Arts and Letters, vol. 16, pp. 421-427, 1931. Published 1932.
Believes that the Triassic conglomerate in the southwest portion of Northampton County is of Brunswick age.

MILLER, BENJAMIN L. The Lehigh Portland Cement District, Pennsylvania.
XVI International Geological Congress, Guidebook 8, pp. 30-40, 2 plates, Washington, 1932.
A concise description of the geology, history and processes of manufacture.

PINE, JOSHUA, 3RD. A Rafting Story of the Delaware River.
Bucks County Hist. Soc., vol. 6, pp. 467-524, Allentown, 1932.
Reprint of some newspaper articles published in 1883. Describes the Delaware River in its passage along Northampton County (pp. 499-508).

SCOTT, WILLIAM BERRYMAN. An Introduction to Geology, Vol. I, Physical Geology.
3d ed., 604 pp., New York, 1932.
Several descriptions or brief references to the Delaware Water Gap. Three cuts of gap, strata exposed and glacial grooving. Lehigh Gap mentioned and cut of slate strata exposed. Also mentioned in first edition, 573 pp., New York, 1897; and second edition, 816 pp., New York, 1907.

SNIDER, LUTHER C. Earth History.
683 pp., New York, 1932.
Brief description and cut of the Delaware Water Gap.

STONE, RALPH W. Building Stones of Pennsylvania.
Pennsylvania Topog. and Geol. Survey Bull. M 15, 316 pp., 4 plates, 164 figures, Harrisburg, 1932.
Brief descriptions of the building stones of Northampton County (pp. 234-239).

STONE, RALPH W. Pennsylvania Caves (Revised Edition).
Pennsylvania Topog. and Geol. Survey Bull. G 3, 143 pp., Harrisburg. 1932.
Discussion of origin of caves, descriptions of cave fauna, and of six caves in Northampton County.

VER STEEG, KARL. Map of the Schooley (Kittatinny) Peneplain.
Jour. Geology, vol. 40, pp. 557-559, Chicago, 1932.
Shows peneplain in eastern Pennsylvania by means of contours. Identifies Kittatinny and Schooley peneplains as the same.

1933

BEHRE, CHARLES H., JR. Slate in Pennsylvania.
Pennsylvania Topog. and Geol. Survey Bull. M 16, 400 pp., 70 plates, 89 figures, Harrisburg, 1933.
An extensive report on slate with many descriptions of the deposits of Northampton County.

CHAMBERLIN, ROLLIN T., and MACCLINTOCK, PAUL. Chamberlin and Salisbury's College Text-Book of Geology, Part I, Geologic Processes and Their Results.
2d ed., 445 pp., New York, 1933.
Cut of Kittatinny Mountain and Delaware Water Gap. Also appeared in first edition of 390 pp., New York, 1927.

HICKOK, W. O., 4TH. Erosion Surfaces in South-Central Pennsylvania.
Am. Jour. Sci., 5th ser., vol. 25, pp. 101-122, 1933. See Ver Steeg, 1930.
Concludes that the wind gaps of the Appalachians in Pennsylvania "fall into narrow horizontal zones which may indicate the presence of several erosion surfaces between 900 feet and 1,650 feet elevation."

VER STEEG, KARL. Windgaps and Erosion Surfaces.
Am. Jour. Sci., 5th ser., vol. 26, pp. 507-511, 1933. See Ver Steeg, 1930.
Disagrees with Hickok. Concludes that in the Appalachian region "there is no accordance in wind gap elevations and that they do not mark fluvial base levels."

WELLS, ROGER C., FAIRCHILD, JOHN G., and ROSS, CLARENCE S. Thorianite from Easton, Pa.
Am. Jour. Sci., vol. 26, 5th ser., pp. 45-54, New Haven, July, 1933.
Describes thorianite, carnotite, autunite and a high thorium gummite from the serpentine locality along the Delaware River, just north of Easton. (Also lists kupfferite (asbestiform)).

1934

ASHLEY, GEORGE H. The Scenery of Pennsylvania.
Pennsylvania Topog. and Geol. Survey Bull. G 6, 91 pp., 90 figures, Harrisburg, 1933.
Contains descriptions of the peneplanes developed in Northampton County. Summarizes the work of F. Leverett and F. Ward on the glacial ice sheets of the region.

COLLINS, W. D., LAMAR, L. W., and LOHR, E. W. The Industrial Utility of Public Water Supplies in the United States, 1932.
U. S. Geol. Survey Water Supply Paper 658, pp. 108-109, Washington, 1934.
Brief descriptions and analyses of the water supply of Bethlehem and Easton.

FRETZ, A. HENRY. The Burden of Lehigh River in One Year.
Pennsylvania Acad. Sci. Proc., vol. 8, pp. 92-94, Harrisburg, 1934.
Gives statistics of the amount of soluble and insoluble material carried past Bethlehem during a year of observation.

FULLER, J. OSBORN. Preliminary Staining Studies of the Lehigh Valley Dolomitic Limestones.
Pennsylvania Acad. Sci. Proc., vol. 8, pp. 83-87, 1 figure, Harrisburg, 1934.
Describes results obtained in staining specimens of the Cambrian and Ordovician limestones of the Lehigh Valley.

HALL, GEORGE M. Ground Water in Southeastern Pennsylvania.
Pennsylvania Topog. and Geol. Survey Bull. W 2, 255 pp., 7 plates, 7 figures, Harrisburg, 1934.
Describes the underground water conditions in Northampton County.

JOHNSON, DOUGLAS. How Rivers Cut Gateways Through Mountains.
Scientific Monthly, Feb. 1934, pp. 129-135, New York, 1934.
Brief description of the history of mountain gaps with references to the Delaware Water Gap and the Wind Gap.

LEVERETT, FRANK. Glacial Deposits Outside the Wisconsin Terminal Moraine in Pennsylvania.
Pennsylvania Topog. and Geol. Survey Bull. G 7, 123 pp., 2 plates, 38 figures, Harrisburg, 1934.
Describes in particular the Illinoian ice sheet in the vicinity of Bethlehem and in the Saucon Valley.

MEYERHOFF, HOWARD A., and OLMSTED, ELIZABETH W. Wind gaps and Water gaps in Pennsylvania.
Am. Jour. Sci., 5th ser., vol. 27, pp. 410-416, 1934. See Ver Steeg, 1930.
"The Appalachian region of Pennsylvania contains the record of several erosional levels of fluvial origin. The positions of these levels are indicated with moderate accuracy by *groups* of water gaps and wind gaps."

MILLER, BENJAMIN LEROY. Limestones of Pennsylvania.
Pennsylvania Topog. and Geol. Survey Bull. M 20, 729 pp., 41 plates, 34 figures, Harrisburg, 1934.
Contains descriptions of the limestone resources of Northampton County.

MYERS, PHILIP B. The Origin of Jaspers in Lehigh and Northampton Counties, Pennsylvania.
Pennsylvania Acad. Sci. Proc., vol. 8, pp. 87-92; 1 figure, Harrisburg, 1934.
The microscopic characteristics of the jasper of the Hardyston formation are described and their origin discussed.

TORREY, RAYMOND H., and others. Guide to the Appalachian Trail, from the Housatonic River to the Susquehanna River.
88 pp., New York, 1934.
Describes the trail on the crest of Blue Mountain between the Delaware and Lehigh Rivers (pp. 49-58) with route maps.

WARD, FREEMAN. Distribution of the Wisconsin Glacier in the Delaware Valley.
Geol. Soc. America Bull., vol. 45, pp. 655-664, 2 figures, New York, 1934.
Describes glacial phenomena in Northampton County. Concludes that the glaciation on the top of Blue Mountain was effected by the Illinoian Ice Sheet and that a narrow tongue of the Wisconsin glacier extended down the Delaware River Valley as far as Carpentersville, N. J.

WARMKESSEL, CARL A. Burden of Lehigh River During the Flood of August, 1933.
Pennsylvania Acad. Sci. Proc., vol. 8, pp. 94-96, Harrisburg, 1934.
Gives figures of kind and amount of material carried past Allentown and Bethlehem during the 1933 flood.

WOOD, LESLIE C. Rafting on the Delaware River.
272 pp., New York, 1934.
The features of the Delaware River are described.

1935

Ashley, George H. Studies in Appalachian Mountain Sculpture.

Geol. Soc. America Bull., vol. 46, pp. 1395-1436, 8 plates, 14 figures, New York, 1935.

Discusses the peneplane problem and specifically refers to Northampton County localities. Concludes that there has been only one period of peneplanation.

Garrison, Hazel Shields. Cartography of Pennsylvania before 1800.

Pennsylvania Mag. of Hist. and Biog., vol. 59, pp. 255-283, 1935.

Among others the work of Lewis Evans, Nicholas Scull, William Scull and Reading Howell is described. All of these include the area now comprising Northampton County.

Hills, John M. The Insoluble Residues of the Cambro-Ordovician Limestones of the Lehigh Valley, Pennsylvania.

Jour. Sedimentary Petrology, vol. 5, pp. 123-132, 3 figures, 1935.

The limestones exposed along the Delaware and Lehigh Rivers were studied in considerable detail. Concludes that "while the method of insoluble residues can not be recommended for independent use in regions of complex structure, it is very valuable as an adjunct to conventional field methods in determining stratigraphic succession and establishing more exact lithological correlations."

Plank, William B., and Fay, Albert H. Influence of Rock Structure on Blasting.

Am. Inst. Min. and Met. Eng. Tech. Pub. 600, 13 pp., 6 figures, New York, 1935.

Metal Mining and Mining Geology, vol. 126, pp. 136-147, 1937.

A description of rock structures in gneiss at Paxinosa Point along the Delaware River above Easton and the resulting effects when portions were blasted down to widen the highway.

Ver Steeg, Karl. Wind gaps and Water gaps; Their Value as Indicators of Erosion Surfaces.

Am. Jour. Sci., 5th ser., vol. 30, pp. 98-105, New Haven, 1935.

Reviews the work of Bascom (1921), Barrell (1920), Knopf (1924), Stose (1928), Meyerhoff and Olmsted (1934). States that "since the water gaps of today have varying elevation and are known not to represent a peneplane of fluvial base level, the still more irregular wind gaps cannot be regarded as reliable evidence of former base levels." See Ver Steeg, 1930.

1936

Fraser, Donald M. Sericitization in the Pennsylvania Highlands.

Pennsylvania Acad. Sci. Proc., vol. 10, pp. 66-71, 1936.

Discusses formation of sericite in pre-Cambrian rocks.

Fraser, Donald M. Paleozoic Pegmatites in the Pennsylvania Highlands.

Am. Mineralogist, vol. 21, pp. 662-666, 1936.

Describes an occurrence in the east end of Morgan Hill.

Gehman, George W. Some Minerals of the Serpentine Range near Easton. Pennsylvania.

Rocks and Minerals, vol. 11, pp. 90-91, Peekskill, 1936.

Describes the occurrence and characteristics of thorianite, thorogummite, uranophane, autunite, carnotite (?), zircon, tremolite, wernerite, molybdenite, pyrite, limonite, serpentine and talc.

Itter, Harry Augustus. The Geomorphology of the Wyoming-Lackawanna Region. 87 pp., Easton, 1936. (Privately printed.)

Discusses ancient drainage in eastern Pennsylvania.

Meyerhoff, H. A., and Olmsted, E. W. Wind- and Water-gap Systems in Pennsylvania.

Am. Jour. Sci., vol. 31, 5th ser., pp. 391-398, New Haven, 1936.

Further discussion of relation between wind gap elevations and fluvial erosion surfaces. See Ver Steeg 1930.

Meyerhoff and Olmsted. The Origins of Appalachian Drainage.

Am. Jour. Sci., 5th ser., vol. 32, pp. 21-42, 1936.

A discussion of the major streams of the Appalachian area including Delaware River. The Triassic conglomerates of Flint Hill are believed to have been formed by the Triassic Lehigh River.

RYDER, C. E. The Floods of March, 1936, in Pennsylvania.
Department of Forests and Waters, Commonwealth of Pennsylvania, 129 pp., Harrisburg, 1936.
Describes the floods of the Lehigh and Delaware Rivers during March, 1936.

STOKES, A. F. Geography and History of Northeastern Pennsylvania.
78 pp., 60 figures and maps, Scranton, 1936. Earlier edition in 1935.
Contains descriptions of the Delaware River and the Delaware Water Gap.

1937

CHIDSEY, A. D., JR. The Penn Patents in the Forks of the Delaware.
Northampton County Hist. and Gen. Soc., vol. 2, 91 pp., 9 maps, Easton, 1937.
Much information regarding early land owners. Reproductions of early maps.

FENTON, CARROLL LANE, and FENTON, MILDRED ADAMS. Cambrian Calcareous Algae from Pennsylvania.
American Midland Naturalist, vol. 18, pp. 435-441, 1937.
Describes *Cryptozoon proliferum fieldii* from Bucks Co., *Dolatophycus expansus* from Raubsville and *Anomalophycus compactus* from Portland, Northampton Co.

FRASER, D. M. Basic Rocks of the Eastern Pennsylvania Highlands.
Am. Geophys. Union Bull., July, 1937, pp. 249-254.
Discusses relationships of the basic rocks in this and adjoining sections.

MILLER, BENJAMIN L. Casts of Halite Crystals in the Beekmantown Limestone.
Pennsylvania Acad. Sci. Proc., vol. 11, pp. 55-57, Harrisburg, 1937.
Description and photograph of halite crystal casts from the dolomitic limestones of Portland, Northampton County.

MILLER, RALPH L. Martinsburg Limestones in Eastern Pennsylvania.
Geol. Soc. America Bull., vol. 48, pp. 93-112, ill., New York, 1937. Discussion, pp. 2032-2037.
Describes some Martinsburg limestones of Northampton County.

MILLER, RALPH L. Stratigraphy of the Jacksonburg Limestone.
Geol. Soc. America Bull., vol. 48, pp. 1687-1718, ill., New York, 1937.
Discusses paleontologic, stratigraphic and structural characteristics of the Jacksonburg as developed in Northampton County and adjoining areas. Briefly describes seven occurrences of volcanic ash within the county.

SHERMAN, L. D. Lehigh River Flood Control Survey.
Works Progress Administration Project 8675, U. S. Engineer Office, War Department, Philadelphia, 1937.
A series of forty-seven blueprint topographic charts of the flood plains of the Lehigh River and lower portions of tributaries from Easton to Laurys. Also profiles of Lehigh and Delaware Rivers and tributaries. Charts on scales of 1 inch = 100 or 200 feet and 1 to 5,000.

1938

ITTER, HARRY AUGUSTUS. Geomorphology of the Wyoming-Lackawanna Region.
Pennsylvania Topog. and Geologic Survey Bull. G 9, 82 pp., 9 plates, 46 figures, 1938.
Discusses ancient drainage systems of eastern Pennsylvania and New Jersey which includes Northampton County.

MACKIN, J. HOOVER. The Origin of Appalachian Drainage—A Reply.
Am. Jour. Sci., 5th ser., vol. 36, pp. 27-53, 1938.
Discusses paper by Meyerhoff and Olmsted published in 1936. Disagrees with the authors and accepts theory of D. Johnson.

WARD, FREEMAN. Recent Geological History of the Delaware Valley Below the Water Gap.
Pennsylvania Topog. and Geol. Survey Bull. G 10, 65 pp., 1938.
Detailed descriptions of the glacial deposits of the Delaware River Valley across Northampton County.

TOPONOMY

By Benjamin L. Miller

The place names of a region and their derivation are of general interest and occasionally possess distinct geographic or historic value. The material here given was collected in a study of the earlier maps and published descriptions of the region. An attempt has been made to make it as complete as possible but doubtless there are omissions. If several different origins have been given for specific names and difficulty has been experienced in determining the correct origin, the various explanations have been cited. Several obsolete names are included.

The names given to the natural features of Northampton County and to the settlements and political divisions reveal several different tendencies, some of which are worthy of mention. It is therefore possible to classify the place names of the county into several groups that will include practically all the names that have appeared on various maps and in other publications. These are briefly described. To save space, only a few names in each group are cited.

1. *Indian names.*—The Indians attached names to some of the most important streams and mountains. These were chosen because of some characteristic feature and were generally compound words; almost complete sentences in some instances. The early settlers endeavored to retain some of these names but with indifferent success. Some of the names were long and were perhaps spoken by the Indians indistinctly or with variations by different individuals. Therefore it is not surprising that when these names were reduced to writing there should be variations. The best example of this in this region is the name "Monocacy." The writer has found in the records and maps thirty-seven spellings as given on a later page. Of course, some of these may be due to typographic errors, carelessness or indifference.

Fortunately, the meanings of many of the Indian names have been preserved to us in a manuscript of John Heckewelder, a prominent Moravian missionary to the Delaware Indians. This manuscript was edited by William C. Reichel for publication in the Transactions of the Moravian Historical Society under the title "Names which the Lenni Lenape or Delaware Indians gave to Rivers, Streams and Localities within the States of Pennsylvania, New Jersey, Maryland and Virginia, with their Significations." (1872) Much valuable matter has been obtained from this source.

When the Indian term was retained by the early settlers there were gradual changes by which eventually a corruption became general.

It is sometimes difficult to trace the present name to its original Indian designation. A good illustration of this is the name "Lehigh" which comes from "Lechauwekink." Very early the name was shortened by the early German settlers to "Lecha" but even that does not sound much like "Lehigh," the modern name which was adopted by the English.

Some other Indian names are Catasauqua, Hokendauqua, Saucon, Tatamy, and Kittatinny. All of these and a few others seem to have been given by the Delaware Indians.

2. *Family names of early residents.*—The names of families or some particular individuals constitute the greatest number of place names of Northampton County. Usually the family name has been selected although in some cases, such as Petersville and Jacoby (Cobus) Creek, the given name has been chosen. The taverns of an early day were almost always known by the names of the proprietors and as these localities developed into settlements the names were extended to include the entire community. When the tavern changed owners the name of the settlement also changed in many cases so that some difficulty is experienced in identifying some of these old place names now in disuse. Creeks and hills likewise have at times borne different names because of the arrival of new families in the particular regions. Creeks were commonly named for a family that operated a mill on the stream.

Some settlements have had their names changed when the U. S. Government established a post office and would not permit duplication of a name used elsewhere within the State. In some cases dual names persisted for some time but eventually the new name chosen for the post office was extended to the village.

As examples of this general class or group of place names, the following are cited: Hellertown, Danielsville, Redington, Hunters Creek, and Roseto.

3. *Names of distinguished persons.*—Several place names of the county perpetuate the name of persons of prominence, some of whom never had any connection with this section. The following are examples: Wilson Township, Pennsville and Siegfried.

4. *Names of Biblical origin.*—As many of the early residents were extremely religious, it is only natural that names such as Bethlehem, Nazareth and Mount Bethel should be applied to some of the settlements.

5. *Names of places from whence the early settlers came.*—In this class we have as examples many names applied by the German settlers,

such as Schoeneck and Hanover; by the English, names such as Bath and Northampton; and by the Welsh and Cornish slate workers, Bangor and Delabole.

6. *Names based on characteristic appearance or location.*—Some place names call attention to a prominent characteristic feature, such as the following: Plainfield, Drylands, Mud Run, Offset Knob, Wind Gap and Blue Mountain.

7. *Names based on the occupations of the inhabitants.*—Such names as Filetown, Slatefield, Smoketown, Aluta and Farmersville illustrate a common custom of naming settlements on the basis of the occupations of the residents.

8. *Fantastic names with little significance.*—In a few cases names with little significance appear on our maps, such as Grand Central, Glendon, etc.

It is not possible to quote all the authorities for the explanation of the place names which follow in alphabetical order. They have been compiled from local histories, travel books, newspapers, and from individuals. Particular credit should be given, however, to three important sources of information. They are as follows:

Heckewelder, John, Names which the Lenni Lenape or Delaware Indians gave to Rivers, Streams and Localities within the States of Pennsylvania, New Jersey, Maryland and Virginia with their significance: Moravian Hist. Soc. Trans., vol. 1, pp. 225-282, Nazareth, 1872.

Donehoo, George P., A history of the Indian villages and place names in Pennsylvania: 290 pp., Harrisburg, 1928.

Espenshade, A. Howry, Pennsylvania Place Names, 375 pp., State College, 1925.

PLACE NAMES

Ackerman Lake; family name.

Ackermanville; for John Ackerman, an early settler who purchased 600 acres in that section.

Albrecht's Brunn; see Christian Spring.

Alburtain's Ferry; see Myers Ferry.

Allegheny Creek; from the Indian term "Allegeni," meaning a "fair or beautiful stream." Also spelled Allegany.

Allen Township; for William Allen, the founder of Allentown and President Judge of the Supreme Court of the Province. Was first called Mill Creek Township. Erected on June 10, 1748; at that time a part of Bucks County.

Alpha; named because of its location near the quarries of the Alpha Slate Manufacturing Co.

Altona (h); said to be a corruption of three German words "all zu nah" (all too near), having reference to a real estate development that proved a failure. A small farm was cut up into small building lots with the idea of establishing a small settlement. The failure to sell the lots was attributed to its nearness to Bethlehem, hence the designation. According to another explanation, the name was given because the church nearby was said to be too near to Bethlehem to be justified. It is also said to have been derived from the Latin word *altus*, meaning "high." Another improbable explanation is that it was named by some of the early German residents for Altona, Germany.

Aluta; formerly known as Mill Grove because of several mills and a tannery nearby. When a post office was established there, that name was denied the residents because of another post office of the same name in the State. Accordingly, a Latin name meaning "soft leather" was adopted because of the local tanning industry.

Anter's Ferry; see Myers Ferry.

Applebutter Street (or Road); much applebutter was made here by early settlers. Originally called "Latwerg (applebutter) Strasse."

Apps; for the App family, early residents.

Arndts; supposedly named for Capt. John Arndt who commanded a company of soldiers during the Revolutionary War, or for his father, Jacob Arndt, who purchased a mill property on the Bushkill Creek in 1760.

Ashland; see Belfast Junction.

Assylum; see Filetown.

Attine's Ferry; see Myers Ferry.

Augusta; a village laid out on the south side of the Lehigh River near the zinc works by Augustus Luckenbach. Now a part of Bethlehem.

Bangor; named from the slate town in Wales by R. M. Jones, a Welsh slate operator who opened slate quarries about 1866. The town was mainly settled by Welsh slate workers. It was incorporated about 1875. On Hopkins (1860) map, the southern portion of the present town was called New Village and the northern portion Uttsville from the Utt family, early residents.

Bassards Corners; family name. On some maps appears as Buzzard, or Bossard.

Bath; a daughter of William Allen, the original owner of the land, married James DeLancey whose home was in Bath, England, and therefore the settlement was named in his honor by the early Scotch-Irish settlers.

Bear Swamp; place favored by bears.

Beersville; for the Beers family, early residents. On an 1830 map by H. S. Tanner called Falmers, a family name.

Bel(l)fast; at an early date called Bellville or Belleville. Evidently named because of the fine view. The present name seems to have been adopted from Belfast, Ireland, and was chosen because some of the early settlers were Ulster Scots.

Belfast Junction; railroad junction near Belfast. Originally called Point Edward. On atlas published in 1874 the place is named Ashland.

Bell(e)ville; see Belfast.

Belvidere Ferry; a ferry across the Delaware River to Belvidere, N. J., was long operated.

Benders Junction; for the Bender family, early residents.

Benningers P. O.; for the Benninger family, early residents.

Berlinsville (also known as **Lehighville**); for the Berlin family that operated slate quarries here.

Bertsch Creek; family name.

Bethlehem, Bethlehem Township; original Moravian settlement, named on Christmas Eve, 1741, from birthplace of Christ in Judea, by Count Nicholas Ludwig von Zinzendorf. Bethlehem Township, erected in 1746, was

then part of Bucks County. The Indians called the site of Bethlehem "Menagachsink" meaning "at the bending creek" probably with reference to the sharp turn of Monocacy Creek where it joins the Lehigh River.

Big Offset; a pronounced offset in Kittatinny (Blue) Mountain north of Bangor.

Bingen; named about 1850 by the Ueberroth family who came from the region of Bingen on the Rhine, Germany. Another explanation is that it was named by F. A. Cornly, President of the North Pennsylvania Railroad Co., because of its German population.

Black River; small stream that at times is very muddy.

Black Tommy's Creek; see Mud Run.

Blue Mountain; from a distance this mountain frequently appears bluish. Also called North Mountain and Kittatinny Mountain. See North Mountain and Kittatinny.

Blue Mountain P. O.; see Delabole.

Boardman's Ferry; see Hartzells Ferry.

Boston; see Johnsonville.

Boston's Creek; see Hokendauqua Creek.

Bougher Hill; for the Bougher family, early residents. Jacob Bucher (later changed to Bougher) bought 206 acres of land there on December 25, 1773. Later called Spring Hill, evidently because of the springs.

Boulton; located on Bushkill Creek between Schoeneck and Belfast. The village was the site of The Henry Rifle Works and named for Matthew Boulton, a metal manufacturer in England.

Brady Lake; family name.

Brandy Hook; see Centerville.

Brodhead; for the Brodhead family, early settlers in the section.

Buchkabuchka; see Lehigh Gap.

Bull Run; probably from Bull Run, Virginia.

Bushkill Creek, Bushkill Township; a Dutch word meaning "bushy stream" applied by the early Dutch explorers. Kill is the Dutch term for stream. Called by the Indians Lehetan, Lehitthan or Lehicton Creek all of which names appear on early maps, meaning "where the writings were drawn," with allusion to the treaties signed at Easton in 1751. Was also called Tatemis (Tatemy's) Creek from the Indian Chief Tatami (Tatamy) and also Lefebre's (Lefevre's) Creek. Lefebre lived near the creek, a mile below Stockertown. Bushkill Township erected in 1814. On 1850 map by M. S. Henry the spelling is Bushkilln.

Butztown; for George Butz who erected a large house there about 1795. Appears as Butzsville on 1830 map by H. S. Tanner.

Butzsville; see Butztown.

Camels Hump; so named because of two knobs forming crest of hill. Has also been called Quaker Hill. On N. Scull's 1759 map and W. Scull's 1770 map is called "Manakisy Hill."

Campbell's Creek; see Jacoby Creek.

Captain John's Village; see Welagamika.

Catasauqua, Catasauqua Creek; corrupted from an Indian term "Gattoshacki" meaning "the earth thirsts" (for rain). The name is written Caladaqua, Caladoque, Calesoque, Calisuk, Colesauque and Collasauque on various old maps and records. Also called Mill Creek by some early residents because of mills on the stream.

Centerville (Centreville); named because midway between Richmond and Williamsburg. Was known as Brandy-Hook until about 1830. The name is said to have originated when a party assembled in a social gathering discussed the naming of the settlement. "It was remarked by Mr. Joseph Wallace, that it is easy to find a name, the only thing necessary was to make the hook, and as there was plenty of brandy, then let it

be called 'Brandy-Hook'." Even earlier was called Stone Church after the old stone church erected in 1794. At one time it was called Nelighsville for Nicholas Neligh who erected a mill there about 1800.

Chapman or Chapman Quarries; for William Chapman who developed the slate quarries of the region.

Charles Hartzell's Ferry; see Myers Ferry.

Cherry Hill; so named because of the abundance of cherry trees in the vicinity.

Cherryville; named from an old lane bordered by about one hundred cherry trees.

Chestnut Hill; the chestnut trees once present furnish the name. A small settlement just north of the hill has been given the same name.

Chickentown; between Bath and Bethlehem. Name probably suggested by the poultry farms of the neighborhood.

Christian Spring; translation of "Christiansbrunn." Named for a son of Count Zinzendorf. Was first called Albrecht's Brunn for John Andrew Albrecht, one of the first group to settle there. The Indians called the place "Nolemattink" or "Nolamattunk," which see.

Christine's Hill; family name.

Chubbsville; see Point Phillip(s).

Church Hill; for a church on the hill.

Churchville; for a church erected there in 1811.

Clearfield; evidently named by early settlers because of absence of trees.

Clyde; named for the Clyde family that owned the land where the station was located when the railroad was built.

Cobus or Cobus's Creek; a shortened form for Jacoby (Jacobus) Creek, which see.

Coffeetown; on 1830 map is called Dimers, later Diemers then Deemer, a family name. Explanation for present name not obtained.

Columbia Station; see Portland.

Craigs Settlement; see Irish Settlement.

Cru(i)kshanks; see Shimersville.

Currie's Ferry; a ferry across the Lehigh near present site of Freemansburg. Was operated by John Currie.

Danielsville; named for the Daniels family, early residents.

Dannersville; named for the Danner family, first residents of the place.

Deckers Ferry; ferry across the Delaware River at Slateford established by George Decker.

Delabole; for Delabole, Cornwall, England, where slate has long been quarried. Was first called Schmalzstadt ("schmalz" means lard) probably because farmers of the region did their own butchering. A post office at the place in 1874 was designated Blue Mountain Post Office.

Delaware River; called by the Delawares "Lenapewihittuck;" i. e., "the river of the Lenape." Also "Kithanne" (in Minsi Delaware Gichthanne) signifying "the main stream" in its section. The Dutch who were the first Europeans to sail up the Delaware named it in contradistinction from the North River, Zuydt or South River. They also called it Nassau and Prince Hendrick's River. The Swedes later called it Sweuska (Swedes) River. It takes its present name from Lord De La Ware (Warr), Governor of Virginia, who "passed the Capes" in 1610.

Delaware Water Gap; so named because of the water gap cut through Blue Mountain by the Delaware River. The Indians called the Gap Pahackqualong (Pahaqualong, Pachoquelin, Pahaqualing) signifying "a mountain with a hole (or gap) in it."

Delps (Delpsburg); for the Delps family, early residents. East Bangor was also originally called Delps or Delpsburg for Andrew Delps.

Depuy (Depui, Depue, also erroneously Depew) Ferry; a ferry across the Delaware River about 3 miles above Martins Creek. Named for owner, a member of the French family that settled north of Blue Mountain prior to 1730.

Depuy Ferry Road; road leading to the ferry.

Dill's Ferry; see Portland.

Dimers (Diemers, Deemer); see Coffeetown.

Douglassville; a settlement near the Douglass slate quarry along Bushkill Creek about one mile northwest of Aluta. Named for the Douglass family.

Dryland and Drylands; the name applied to that region lying between Bethlehem and Nazareth that contains few surface streams.

Drylands Pond; see Green Pond.

Dry Run; a stream near Northampton that is frequently dry. Also see Mud Run.

Durham and Reading Hills; the chain of mountains running between the Delaware and Schuylkill rivers from Durham Furnace to Reading, and including the mountains known as Lehigh Mountain or South Mountain(s). Both Durham and Reading were named for English towns.

East Allen Township; erected from Allen Township in 1845. See Allen Township for name.

East Bangor; village lying to east of Bangor. Formerly known as Delps or Delpsburg for Andrew Delps who founded the village in 1856.

East Branch, East Fork; applied to east branch of several streams.

Easton; named by Thomas Penn in 1751 for the estate of Easton Neston, belonging to his father-in-law, the Earl of Pomphret (Pomfret). The estate was in Northamptonshire, England. The old name was "The Forks of the Delaware" which was usually applied to the entire area of Northampton County north of the Lehigh River but occasionally to the more restricted area where the Lehigh and Delaware rivers join. The Indian name was "Lechauwitank" meaning "in the forks." Erroneously the name has been stated to have been given "because of its eastern position in the State."

Edelman; family name.

Edgemont; probably named because of its location near the base of Blue Mountain.

Elephant Rock; a rock of elephantine proportions.

Emanuelsville; the family name of Emanuel appears in the early records of the county and probably furnishes the name. Appears on 1860 map by Hopkins as Immanualsville.

Emery Island; family name.

Factoryville; some manufacturing enterprises explain origin.

Falmers; see Beersville.

Farmersville; named because farming is the principal occupation of the residents of the region. Was called Lawalts, a family name, at an early date (on 1830 map).

Filetown; named because at one time a considerable portion of the inhabitants were employed in the filing of gun locks for the Henry Rifle Factory on the Bushkill nearby (see Boulton). Until 1840 it was known as Assylum, as Moravian couples expelled from the Moravian colonies for transgressing the rules of morality took temporary refuge here in a large stone house. Some of them settled in the community.

Flatfield; a small settlement on Martins Creek laid out by William McCalla about 1812. Named because of the flat land.

Flicksville; named for John Flick, the first settler.

Flint Hill; the hill at south end of Lower Saucon Township that has quantities of quartz and quartzite cobbles in soil. Also called Grubsberg or Grubbsberg because of the abundance of cobbles that had to be grubbed (dug) out of the fields.

Forks North; see Mount Bethel.

Forks-of-the-Delaware; a term in common use in the early settlement of the region. It included the entire area bounded by Blue Mountain, the Lehigh and Delaware rivers. The Lehigh River was called the West Fork of the Delaware. The Indians called the area Lechauwitank (also Lechauwake or Lechau-hanne) meaning "where there are forks."

Forks Township; includes the region lying north of the Lehigh and west of the Delaware River formerly known as "The Forks of the Delaware." At one time before the establishment of Northampton County, the Township, then a part of Bucks County, included all of the present Northampton County with the exception of Lower Saucon and Williams townships. Was incorporated in 1754.

Foul Rift; named for rapids in the Delaware River; the upper rift near Belvidere, the lower and larger one about two miles below. In 1772 a passage was cut, making it possible for boats to pass. Ferry across the Delaware River at this place was called Foul Rift Ferry.

Fousts Ferry; located near present boroughs of Coplay and Northampton. Family name.

Fox Gap; named for Christopher Fox who was residing in that section in 1776.

Freemansburg; named for Jacob Freeman who settled there on the completion of the Lehigh Canal. He was a son of Richard Freeman who settled opposite (on the south side of the Lehigh) about 1763.

Friedensthal; means "valley of peace." Was located on the Bushkill Creek near the present site of Tatamy. Moravians erected a mill here in 1749. A stockade about the mill afforded protection to the settlers during the Indian troubles.

Frya Run; family name. Originally called Kleinhans' Run and so designated on early maps. Also called Frys Run.

Fucht Hill; family name.

Gaffney Hill; family name.

Georgetown; named for the George family, early residents of the region.

Glendon; village named for the Glendon Iron Works established there in 1867.

Gnadenthal; a settlement about 2 miles west of Nazareth established by Moravians in 1745 for the "Married Brethren." In 1837 it was sold to the Commissioners of Northampton County as the seat of the County Alms House.

Grand Central; railroad station humorously named.

Granite Hill; hill composed of hard crystalline rocks.

Green Pond; a small pond with green trees and other vegetation about, in Bethlehem Township. Also said to have received name from the green scum on the surface during periods of drought. At an early date it was known as Drylands Pond.

Greenwalk Creek; probably refers to attractive path along creek.

Grubs Berg (Grubbsberg); the hill lying to the southeast of Iron Hill, where low dwarf oak trees grew. Also see Flint Hill and Iron Hill.

Gruvertown; family name applied to a small settlement about one mile north of Mt. Pleasant.

Hanover Township; named for Hanover, Germany, the former home of many of the early residents. Was erected in 1798 from part of Allen Township. When Lehigh County was erected in 1812 most of Hanover Township was taken into the new county.

Hanoverville; same derivation as Hanover. The post office at one time was called Hanover.

Harmony Ferry; a ferry across the Delaware River to Harmony, N. J., about five miles above Easton. At an early date (1753) was called Hunter's Ferry.

Harpers; named for the Harper family.

Hartzels; see Newburg.

Hartzells Ferry; named for Jackson Hartzell who operated a ferry here. At different times it was called Mack's Ferry (1783), Boardman's Ferry and William Emery Ferry, taking the name of the current owner.

Haynes Mill; named for the owner of the mill.

Hecktown (also known as Heckertown or Hectown); said to have been so named because a Moravian passing between Bethlehem and Nazareth stopped there at the tavern and observing several children playing in the mud road remarked that "if those people were of no service to the community yet, says he 'sie können gut hecken' meaning they breed well." (Ms. of M. S. Henry).

Hellertown; named for Christopher and Simon Heller, early settlers in the region who came from Germany in 1738. Also spelled Hellerstown. The first resident is said to have been Michael Heller.

Hellerville or Hellers; see Wind Gap.

Hexenkopf Hill; was early known as Hepikoft Hill and later Hexenkopt (Witch's Head). Was an Indian shrine and by the early white settlers supposed to be the habitation of witches.

Hexenkopf Rock; large rock on Hexenkopf Hill.

Hokendauqua, Hokendauqua Creek; name corrupted from *Hackiundochwe*, signifying "*searching for land*." (Note. Probably some whites were observed by the Indians surveying or prospecting along the stream.) Other spellings were:

Hockandauqua	Hockendoque	Hokendauqua
Hockendauqua	Hockyondocquay	Hookiendocque
Hockendauquo	Hockyondoque	Hookyondocque
Hockendock	Hocqueondocy	Hoquendoquy
Hockendocque		

On a map published about 1795 the creek is named Boston's Creek. An Indian village was located near the mouth of the creek. Near it the walkers of the 1737 Walking Purchase are said to have spent the first night. Village was called Hockyondocquay.

Hollo; two neighbors after a quarrel refused to speak. Some time after meeting one greeted the other with Hollo, to which the other responded in the same way. Other residents afterwards called the place Hollo. Also written Hallo.

Hopesville (Hopeville or Hope's Lock); family name. Name of Mr. Hope appears on a map published in 1850.

Horn Springs; probably an error and should be Hahn Springs from a nearby land owner named Hahn.

Howersville; a hotel and store were operated here by Col. A. Hower.

Howardtown; old name of Howertown.

Howertown; for Frederick Hower who lived here as early as 1774. Also called Howerton and Howardtown.

Hunter's Creek; for William Hunter, founder of Hunter's Scotch-Irish settlement. Name now changed to Jacoby Creek. In Mount Bethel Township. See Jacoby Creek.

Hunter's Ferry; see Harmony Ferry.

Hunter Settlement; see Upper Mount Bethel Township.

Indian Creek; named because of the early Indian inhabitants.

Indianland; same as Indian Creek. Name applied to a considerable area, 6500 acres, in the southeast part of Lehigh Township where Thomas Penn planned to establish all the Indians of the Forks (the region bounded by the Lehigh and Delaware rivers and Blue Mountain). A survey was made in 1735 but the project was then dropped. At one time called Poplar Grove because of the poplar trees.

Irish Settlement; name applied to the region lying between Bath and Weaversville that was settled by a colony of Scotch-Irish under the leadership of Thomas Craig about 1728. The settlement of Scotch-Irish in northeast part of county also given same name at times. See Upper Mount Bethel Township.

Iron Hill; said to have been named because of iron ore being found there although so far as known no iron was ever mined. Was earlier called Grubs Berg by the early settlers. Is now part of Bethlehem. Was a post office in 1860. More recently another hill lying to the southeast has been called Grubsberg. See Flint Hill.

Ironville; a small settlement in the eastern part of Lower Saucon Township. Named because of the iron mines in the vicinity. More commonly called Wassergass, which see.

Island Park; see Smith Island.

Jacksonville; probably named for the Jackson family.

Jacobsburg; for Jacob Hunter who settled there about 1740.

Jacoby Creek (also called Jacobus and Cobus Creek); named for Jacobus Decker, a Hollander who resided on the opposite side of the Delaware River in New Jersey. At one time it was called Hunter's Creek in honor of William Hunter, the founder of Hunter's Settlement. Has also been called Campbell's Creek for Alexander Campbell who owned property through which the stream flows.

Johnson's Swamp; family name.

Johnsonville; for Gilbert Johnson, its founder. Was formerly known as Roxburg from the Roxburg Hotel, the name chosen by owner (Rocksburg). The post office was called Kantatinchunk (see Kittatinny) in 1850 and Boston in 1860.

Jones's Mill; a name appearing on the Scull 1759 map. Located on Bushkill (Lehietan) Creek near present settlement of Walters.

Kantatinchunk; see Johnsonville.

Katellen; village named for Kate Ellen Brodhead whose father was instrumental in building the railroad through the region.

Keifers (Keefer's) Island; named for the Keifer family.

Keplerville; a small group of buildings in eastern part of Plainfield Township named for Peter Kepler who kept a store and tavern.

Kernsville; a name sometimes applied to Petersville in honor of Nicholas Kern.

Kesslers (Keslers); named because of a hotel at this place operated by J. G. P. Kesler.

Kirchberg; named because of church (kirche) built on the hill.

Kithanne; see Delaware River.

Kittatinny (Blue) Mountain, Kittatinny Valley; a corruption of the Indian name "Kantatinchunk," meaning "the main or principal mountain." Also said to have been derived from the Indian term "Kekachtauanim" meaning "endless mountains."

Klecknersville; for a Mr. Kleckner who ran a store there.

Kleinhans' Run; family name. See Frya Run.

Knechts; for the Knecht family, early residents.

Kohlberg (Coal Hill); named because of the large amount of charcoal made there for the Durham Iron Works. In 1787 called "Spring Hill."

Kreidersville; named for Conrad Kreider, a native of Switzerland who early settled here, kept a tavern as early as 1774, and laid out the village in 1805.

Kuntzsford; see Treichlers.

Lafever (Lefebre); see Tatamy.

Latwerg Strasse; see Applebutter Street.

Laubachsville, see Northampton.

Laurel Hill, Laurel Swamp; presence of laurel.

Lawalts; see Farmersville.

Lechauwitank; see Easton.

Lechaw (Lechay, Lecha); see Lehigh River.

Lefebre's (Lafever) Creek; see Bushkill Creek.

Lehietan (Lehicton) Creek; see Bushkill Creek.

Lehigh Gap; gap made in Blue Mountain by the Lehigh River. The Indian name was "Buchkabuchka" meaning "mountains butting opposite each other."

Lehigh (Lecha, Lechaw, Leheigh, Lehi) Mountain; see South Mountain.

Lehigh River; named by Delaware Indians Lechauwe(e)ki (Lechaweki, Lechauwiechink, Lechauwekink, Lechaweing), "where there are forks" or "the fork of a road," of which the present name is a corruption. Heckewelder states "this name was given to the river, because through it struck an Indian path or thoroughfare coming from the lower part of the Delaware country, which thoroughfare, on the left bank of the river *forked off into various trails*, leading North and West." Other writers believe that the name was given because of the stream being a fork of the Delaware River. Was originally called the West Branch of the Delaware. Also called Lecha, Lechaw, Lechay, Lechy, Lehi and Lehy. On most of the maps prepared between 1750 and 1800 it is written Lecha. Germans shortened term to Lecha and English adopted present form.

Lehigh Township; erected in October 1752, was named by the Court. The inhabitants at the time requested the Court to name the township Seimsy in honor of an Indian by the name of Seim, an early Moravian convert.

Lehigh Valley; frequently called Lecha Thal.

Lehighville; see Berlinsville.

Leithsville; for the Leith family, early settlers and large property owners in the region.

Lenapewihittuck; see Delaware River.

Lime Ridge; see Redington.

Little Bushkill; east branch of Bushkill Creek. See Bushkill. It appears that this stream was called Lefebre's (Lefevre's) Creek although this name was applied to the larger stream on certain maps.

Little Gap; small gap or notch in Blue Mountain. Was early called "Die Klee Kaft" or "Die Kleine Kaft."

Little Martins Creek; eastern tributary of Martins Creek.

Little Offset; minor offset in Blue Mountain, north of Bangor.

Lockport; named because of a lock in the canal at that point.

Lost Cave; long known as Hellertown Cave. Present name given when it was reopened as a commercial venture. Name has no significance.

Lower Mount Bethel Township; erected in 1787. See Mount Bethel for derivation of name.

Lower Nazareth Township; erected in 1807. See Nazareth for derivation of name.

Lower Saucon Township; erected in 1742. See Saucon. The first settlers were Mennonite Baptists who are believed by some to have arrived in this township about 1718. Nathaniel Irish was one of the first to be definitely named. He is reported to have arrived as early as 1720 and as late as 1728. He built the first grist mill in the country, near the mouth of Saucon Creek.

Macada; name proposed by William H. Best for the post office established there while John Wanamaker was Postmaster General. Name derived from "macadam" as it was proposed at that time to have the road that passes by the place macadamized.

Mack's Ferry; see Hartzells Ferry.

Mammy Morgan's Hill; see Morgan(s) Hill.

Manunka Chunk Island (N. J.); island in the Delaware River at different times given the family names of Dildine and Mack.

Martins Creek; for James Martin who erected the first grist mill in this section. Was first called Turnami Creek. The Indian name was Sahhonnotung (Sahhawotung) meaning "the place where eels are caught." On an 1850 map by M. S. Henry it is called Molawnquioteouk or Martins Creek.

Martins Creek Ferry; a ferry across the Delaware River near mouth of Martins Creek.

Martinsville; see Martins Creek.

Menagachsink; see Bethlehem.

Middaghs P. O.; for Derrick Otter Middagh, a Dutchman who came to the region in 1730 with the group of Scotch-Irish and Dutch.

Middletown; small settlement about midway between Freemansburg and Butztown.

Millers; for the Miller family.

Mill Creek; see Catasauqua Creek.

Mill Grove; see Aluta.

Molawnquioteouk Creek; Indian term, meaning unknown. See Martins Creek.

Monocacy Creek; corrupted from *Managassi*, *Menagassi* or *Manakessi* signifying "a stream with several large bends." *Managachsink* was the name given by the Delawares to the site of Bethlehem at the mouth of the creek. The following are the various other spellings found in old records and on old maps:

Manacassee	Manookisy	Monockicey
Manakasie	Manoquesy	Monockozy
Manakasy	Menagassi	Monokasie
Manakesey	Menakasie	Monokasy
Manakesie	Menakasy	Monokesey
Manakesy	Monakasy	Monokesy
Manakisy	Monakisy	Monokessy
Manocacy	Monacacy	Monokisy
Manockisy	Monacasy	Monokissy
Manokacey	Monocasy	Monokosey
Manokasy	Monocaisy	Monoquacy
Manokesy	Monockacey	Monoquasy

Moody's Run; see Mud Run.

Moore Township; erected in 1765 in honor of John Moore, a representative of the county in the Provincial Assembly of 1761-1762.

Mooresburg; old name for Moorestown. Named in honor of John Moore.

Moorestown; in honor of John Moore.

Morgan(s) Hill, Morgan(s) Valley; for Mrs. Elizabeth Bell Morgan, the widow of Dr. Abel Morgan, who conducted a tavern on the hill overlooking The Forks of the Delaware (Easton) for about fifty years. Sometimes called "Mammy Morgan's Hill."

Mount Bethel; biblical name chosen for first church erected here by David Brainard, an early and forceful missionary. Originally called "Forks North." Was called Williamsburg (which see) as late as 1894.

Mount Pleasant; named because of the attractive natural surroundings.

Mount Washington; name given to high limestone bluff on south side of Lehigh River at its junction with the Delaware River. Named for George Washington.

Mud Run; named because of its muddy condition at times. At an early period it was called Smalley's Creek, Black Tommy's Creek, Dry Run, Moody's Run and Muddy Creek for names of residents and condition of stream.

Muddy Creek; see Mud Run.

Mutchlertown; a small village southwest of Odenweldertown, both of which now constitute the western part of Easton. Named for Col. Valentine Mutchler who erected the Spring Grove Hotel at that place.

Myer(e)s Ferry; a ferry across the Delaware River about five miles below Portland. Named for one of the later owners. Has also been known as Attine's Ferry, Alburtain's Ferry, Anter's Ferry, Charles Hartzell Ferry, owners at different times.

Nancy's Run; named for an old colored woman who lived along the stream and who became a quite famous fortune teller.

Nassau River; see Delaware River.

Nazareth; named from the town of Galilee in Palestine. Borough settled by Moravians and by George Whitefield. The tract of 5000 acres was purchased from William Penn for £2200 in 1740. In 1741 it was sold to the Moravians. "It was known as the Barony Nazareth because when in 1682 it was granted to his daughter Letitia by William Penn, on the condition of rendering service to him and his heirs by paying, if demanded, a red rose in June of each year forever, it was invested with the right of court baron."

Nelighsville; see Centerville.

Newburg (Newberg); so named when about 1755 a new tavern was built here by Jacob Hartzell. Was also known as Hartzels or Hartzells.

Newcenterville; evidently so named when laid out because of its location with reference to Bath and Nazareth.

Newhartport; for the Newhart family which settled here.

Newharts(ville) P. O.; see Pennsville.

New Market; see Portland.

Newport; name applied to a small settlement on the north side of Hokendauqua Creek near its mouth. Now a part of Northampton.

Newtown; named when established as a new village.

New Village; see Bangor.

Nisky; for Niesky, in Upper Lusatia. Settlement begun by the Moravians who were exiled from Bohemia.

Nisky Hill; name of cemetery hill in eastern part of Bethlehem. M. S. Henry in his history of the Lehigh Valley (p. 227) says that the term comes from the Delaware Indian "Niskeu" meaning "a swamp or wet place, in allusion to the swampy grounds at the foot of the hill."

Nolemattink (Nolamattink, Nolamattunk); was applied to the locality of Christian Spring and Gnadenthal. Heckenwelder says it signifies "where the silkworm spins—the silkworm lands." In June 1752 Rev. Philip C. Bader moved his cocoonery from Bethlehem to Christian Spring where there were many mulberry trees. Perhaps the presence of the mulberry trees furnished the name.

Northampton Borough; formed by the consolidation of Stemton and Siegfried. For derivation of name see Northampton County. At one time the south part—Stemton—was called Laubachsville or Laubach for the Laubach family. See Laubachsville, Siegfried and Stemton.

Northampton County; named from the county of Northampton in England where Thomas Penn's father-in-law, the Earl of Pomfret (Pomphret), had an estate called Easton Neston.

Northampton Heights; now a part of Bethlehem. See Northampton County for derivation of name.

North Mountain; name early given to Blue Mountain because of its location on north side of the Great Valley.

Odenweldertown; now a part of West Easton. Named for John Odenwelder who laid out the village.

Offset Creek; creek near the offset in Blue Mountain. The Indian name was Pocokannd (?) meaning the idea of a stream issuing between two hills.

Offset Knob; offset in Blue Mountain.

Old Sow Island; reason for name being applied is not known.

Oquiston (Oquachton) Creek; see Richmond Creek.

Otis Hill; family name.

Oughoughton Creek; formerly known as Oquachton or Oughquoghton. Is derived from a Delaware Indian name "Ockhucquanhanne" meaning a bend in a stream in the shape of a hook. This bend is near its mouth.

Palmer Township; erected on May 5, 1857. Named for George Palmer who was a State surveyor.

Paxinosa He'ghts; settlement on top of Chestnut Hill north of Easton. Named for an Indian chief Paxnous (Paxinosa).

Pen Argyl; incorrectly said to have been named for William Penn and the Duke of Argyl. Founded in 1868 by Welsh slate laborers. Name suggested by Rev. Sylvester Wolle, President of the Pennsylvania Slate Co. who combined the Welsh word *Pen* meaning *mountain* and the Latin word *Argilla* meaning *clay* or *slate* (being clay converted into slate). Pen also carries the meaning of *head* or *chief.*

Pennsville; named for the Penn family. On Hopkins' map (1860) the place is called Newhartsville P. O. Also called Newharts, a family name.

Petersfield, Petersville; for Peter Miller who, with Nicholas Kern, built a grist mill here in 1805. Originally called Kernville or Kernsville, which see.

Pine Top; named because of pine trees on the hill.

Plainfield Township; so named because when organized in 1762 most of it was an open field with very little timber except along the streams. Earlier the section was called "The Plains." The early Dutch settlers north of Blue Mountain are said to have given the name of Blanveldt (plain field) to the district as it had only small trees and shrubs owing to the fact that the Indians repeatedly burned the underbrush which drove the game through the Wind Gap where the hunters lay in wait.

Point Edward; see Belfast Junction.

Point Phillip(s); for a Mr. Phillips who was proprietor of a hotel just south of point where a prominent early road forked. At an early period humorously called Chubbsville because of a small fish (chubb) having been found in a bottle of liquor served by the proprietor of the hotel, who had diluted the liquor with water from a nearby spring.

Pocokannd (?); see Offset Creek.

Poke Valley, Poke Valley Run, Polk Valley; said to have been named because of the number of small green herons (shite pokes) *Butorides virescens* that one time frequented the region. At an early day was called Schnippe Thal because of the snipes (herons?) common there. Also said to have been named because of the abundant growth of the poke berry plants. Erroneously at times designated Polk Valley in honor of President Polk.

Pomfret; for the Earl of Pomfret (Pomphret), Thomas Penn's father-in-law.

Poplar Grove; see Indianland.

Portland; the borough was originally known as Dill's Ferry, from Henry Dill who kept a tavern and operated a ferry there in 1817. Later it was called Columbia Station from town of Columbia across the river in New Jersey. On an 1850 map by M. S. Henry it was called New Market. The post office there at one time was called Dillsferry P. O. Probably given present name by Capt. James Ginn from Portland, Maine.

Prince Hendrick's River; see Delaware River.

Quaker Hill; name erroneously applied to Camels Hump. Presumably named because of some Quaker residents in the vicinity.

Rasleytown; for the Rasley family. Conrad Rasley, a German settler, came to this country before the Revolution.

Raubs Island, Raubsville; for the Raub family, early settlers. At this point Peter Raub maintained a ferry.

Redington; for Walter Redington who operated limestone quarries at the place. First called Lime Ridge because of lime kilns in the vicinity.

Reederstown or Reedersville; see Williamsburg.

Richmond; probably a family name but possibly named for Richmond, Virginia.

Richmond Creek; same origin as Richmond. Originally called Oquiston or Oquachton Creek. The name means a stream meander in the shape of a hook.

Rismiller; for the Rismiller family, early residents.

Riverton; named for its location on right bank of the Delaware River.

Rockville; a small settlement about 1½ miles west of Youngsville. Named because of a slate quarry nearby.

Roseto; for Nicola Roseto who built the first house in the town about 1884.

Roxburg; see Johnsville.

Rum Corner; see Williamsburg.

Sahhonnotung (Sahhawotung); see Martins Creek.

Sandts Eddy; for Adam Sandt, an early German immigrant who settled in that section prior to 1800.

Santee, Santee's Mill; so named because of a grist mill operated there by J. Santee.

Saucon, Saucon Creek, Saucona; derived from Sakunk, a name apparently first applied to an Indian village at the mouth of Saucon Creek, and afterward to a large tract of country lying on both sides of the creek from its source to its mouth. Sakunk was derived from "Sa-ku-wit" meaning "the mouth of a creek."

Saylorsburg Junction; railroad junction, one branch going to Saylorsburg, Monroe County.

Schernertown; small settlement north of Chestnut Hill about two miles west of Delaware River. Similar name applied to settlement on the Delaware River. See Shernerville.

Schmalzstadt; see Delabole.

Schnippe Thal; name given to a small valley in the southeastern part of Lower Saucon Township "because of the snipes that frequented the brook that flows through it." See Poke Valley.

Schoeneck Creek, Schoeneck Village or Settlement; named after an estate in Austria belonging to Count Zinzendorf upon which some Moravian families were given refuge. The name means "beautiful corner." The village of Schoeneck was commenced in 1760 and officially named on June 7, 1762. On Melish's map published in 1825 the village was called "Edmonds."

Schoenersville (Schoenerville); for Adam Schoener who opened the Blue Ball Tavern there in 1784.

Schoenertown; a name once applied to the cluster of houses along the Delaware River in northeast Easton; a family name.

S(ch)waben Berg; "the hill in the intervening valley of which a number of the first settlers located who had emigrated from Swabia in Germany." Is in eastern part of Lower Saucon Township. Later called Swovenberg.

Seemsville; for the Seems family, early residents of the region. Store was run by a man named Seems.

Seidersville; for Charles Seider, an early resident.

Seipsville; for Peter Seip who purchased land there about 1760 and erected a tavern.

Shernerville (Shernertown); a community on the Delaware River about three miles above Easton. Probably a family name although no record of a family by that name living there has been obtained.

Shimers; site of Samuel Shimer's grist mill on Monocacy Creek.

Shimertown; see Wagnertown.

Shimersville; for Jacob Shimer, an early settler in that section. On early maps appears as Cru(i)kshanks. Named for George Cruikshank who purchased a tract of land near the mouth of Saucon Creek from Nathaniel Irish in 1743.

Shoenersville; see Schoenersville.

Siegfried; for Col. John Siegfried, a Revolutionary soldier who located on the west side of the Lehigh River in 1770 and operated a tavern and ferry. Is now a part of Northampton Borough.

Silver Creek; a clear attractive stream.

Slatefield; named because of slate quarries in the vicinity.

Slateford; named because of a slate quarry operated by James M. Porter about half a mile northwest.

Slateford Creek; named for the slate quarries in the vicinity.

Slate Valley; small settlement about 1½ miles southeast of Danielsville. So named because of slate quarries in the valley.

Smalley's Creek; see Mud Run.

Smith Gap; family name of early residents.

Smith Island; family name. Also known as Island Park. A summer resort was once located on the island.

Smoketown; a log house erected here without a chimney and used for smoking meat by some of the people ln the neighborhood has furnished the name to the settlement.

Snufftown; see Williamsburg.

Sours Mills; family name.

South Bethlehem; originally Augusta (which see), Wetherill (which see), Bethlehem South and now a part of Bethlehem.

South Easton; that part of town located south of the Lehigh River on top of Mt. Washington. The portion along the Delaware River was formerly called Williamsport for the Williams family.

South Mountain; named because of its position on the south side of the valley. Also called Lehigh Mountain and Lecha (Lechaw) Mountain. Constitutes a part of the Durham and Reading Hills.

Specktown; small settlement near Bingen. Named for the Speck family.

Spring Hill; see Bougher Hill and Kohlberg.

Spring Valley; a large clear spring is located here.

St. Anthony's Nose; a cliff at east end of Chestnut Hill that suggests the profile of an Indian's face, particularly the nose.

Steel City; so named because largely occupied by workers in the Bethlehem Steel Co. plant.

Steeleys (Steelys) Hill; family name.

Stemton; named for George H. Stem in 1867 when he established a factory for the manufacture of carts and wagons. Name abandoned when the borough united with Siegfried to form Northampton. Was also known as Laubach or Laubachsville for J. A. Laubach, mill proprietor.

Steuben Station, Steuben (Steuben Town); named for the Steuben family that owned property at this point.

Stier Station; family name.

Stockertown (once called Stockersville); named for Andrew Stocker who built a tavern there about 1790.

Stoke Park; named for Stoke Park, England.

Stone Church; name given to the Union church about 1½ miles north of Kreidersville, built about 1790 for the joint use of Lutheran and Reformed congregations.

Stopes (?); a partly illegible name appearing on Scull's 1759 map near south end of the present Borough of Hellertown.

Stout's, Stout's Valley; for Major Isaac Stout, an officer in the war of 1812, a member of the Legislature and postmaster of the town.

Summerville; probably the village now called Churchville.

Summit; top of hill.

Sweuska (Swedes) River; see Delaware River.

Switchback Road; a back road that formerly was usually in poor condition, and road on opposite side of mountain usually preferred.

Swoveberg; name applied to the eastern part of Lower Saucon Township because most of the early settlers came from Suabia (Swabia), Germany. They were principally weavers from Wurtemburg. Also called Swabenberg or Schwaben Berg.

Tatamy; named for Chief Tatamy of the Delaware Indians who was prominent in the colonial history of the State. He lived in Forks Township near present village of Tatamy where he was granted a tract of land by the Proprietaries. He was shot near Butztown in 1757 by a 16-year-old boy. On Scull's 1759 map the place is called Lafever from an early resident.

Tatemy's Gap; see Weygadt and Tott Gap.

Tatemis Creek; see Bushkill Creek.

Thomas Island; family name.

Three Church Hill; location of three churches.

Totts (Tot, Tott, Tots) Gap; a corruption of Tatamy, the name of an Indian Chief living near Easton. Was first called Tatamy's (Tatami's) Gap. Appears on an 1830 map by H. T. Tanner as Tat's Gap.

Treichlers; for Henry Treichler who operated a grist mill at that place. Earlier known as Kuntzsford from the Kuntz family.

Turnami Creek; see Martins Creek.

Uhlersville; a village laid out about 1830 by Peter Uhler at his lime kilns.

University Heights; settlement on top of South Mountain. Named because of the proximity of Lehigh University.

Upper Mount Bethel Township; erected in 1787. Was first known as the Hunter Settlement. First settled by the Scotch-Irish under the leadership of William Hunter about 1730. For derivation of name see Mount Bethel.

Upper Nazareth Township; erected in 1807. See Nazareth for derivation of name.

Uttsville; see Bangor.

Wagnertown; named because a hotel here was operated by Henry Wagner. Was previously called Shimertown for the Shimer family.

Walnutport; evidently named because of the presence of walnut trees.

Walters; for the Walters family, early residents.

Waltz Creek; probably a modification of Walz Creek, a family name.

Wardsburg; settlement about half a mile from Belleville (Belfast) was named for the original owner of the land, Benjamin Ward.

Washington Township; erected in 1871. Named for George Washington.

Wassergass (Wassergas); two derivations have been offered, both of German origin. According to one the name means "water street or road" from a small stream that heads nearby. The other explanation is that the "springy nature of the land" suggested the name. Also see Ironville.

Weaversville (also called Weaversburg); for Michael Weaver who settled there about 1790. He was the first postmaster, the post office being established in 1831.

Weiders Crossing; family name.

Welagamika (Welagesn, Welagesniko); signifying "fine rich soil." The name of a Delaware Indian town on the "Nazareth tract," when the Moravians went there in May 1740. The Indians applied the name to the entire "Nazareth tract." The town was located about half way between Nazareth and Schoeneck on the east side of the road. There were many peach and plum trees and fields where corn and pumpkins were grown. Wild grapes, hazelnuts and strawberries were plentiful. It was also known as "Captain John's Village" from the Chief. The village was vacated in 1742 when the Indians moved beyond Blue Mountain.

Werkheiser; for the Werkheiser family, early residents.

West Bangor; west part of Bangor.

West Branch (Fork) of the Delaware; see Lehigh River.

West Easton; formed of Odenweldertown and Mutchlertown, which see.

West Fork (of Martins Creek)

Wetherill; the name applied to the settlement on the south side of the Lehigh River now a part of Bethlehem. Named for Samuel Wetherill, superintendent of the zinc oxide plant located there.

Weygadt or Weygat; a Minsi Indian name meaning "white froth" because of white froth on the river water at this point due to the rapids. Another explanation is that it was named by the Low Dutch from two words meaning "wind gate." Has also been called Tatamy's Gap. May be a corruption of a family name as a stone house in Forks Township is said to have been built in 1740 by a man named Weygandt. Is also claimed that the present name is a corruption of Whorrogott, a name given by the early Dutch settlers north of Blue Mountain. It means a place where the waters disappear.

Whip-poor-will Island; evidently named because of the presence of whip-poor-wills.

William Emery Ferry; see Hartzells Ferry.

Williams Township (also written Williamstown); named about 1748 for John Williams, an early settler. Township erected in 1750. Another rather doubtful explanation for the name is that much of the territory now included within the township had belonged to William Penn, a descendant of the great William Penn and was known as "William's Land."

Williamsburg; see Mount Bethel.

Williamsburg (Williamsport); named for William Landers in 1815. Was at an early date known as Rum Corner, because of an incident connected with the erection of a store building when one of the group broke a bottle of liquor by striking it against the building and shouting the name "Rum Corner;" also as Snufftown because of the amount of snuff used by a tavern keeper there. Has also been called Reederstown or Reedersville for Abraham Reeder who owned land there.

Williamsport; see South Easton.

Wilson Borough, Wilson Township; for President Woodrow Wilson. Township was incorporated in 1914.

Wind Gap; takes its name from the gap in Blue Mountain, the first prominent gap west of the Delaware Water Gap and through which no stream now passes. Early German settlers called it "Die Wind Kapf." The north part of the present village of Wind Gap was formerly called Hellerville (1860 map by Hopkins) or Hellers on account of a hotel there being run by J. Heller.

Youngsville; for Ephraim Young who ran a store there.

Zuydt River; see Delaware River.

CLIMATE AND WEATHER OF THE LEHIGH VALLEY

By Benjamin L. Miller

The climate and weather of any part of the country are of extreme and increasing interest and value both to the residents of the particular section and to outsiders. Part of this interest is merely curiosity but generally it represents much more. So many of Man's activities are affected or controlled by meteorological conditions, it is only natural that the weather should be an almost universal topic of daily conversation. Scarcely an individual exists for whom weather does not play a most important role. Illustrations of this connection will occur to anyone who gives the matter thought. A few examples that are probably not generally recognized are offered.

The extremes and the duration of cold and heat are economic problems that determine the depth at which water pipes should be laid, the amount of insulation needed, the amount of fuel required, and the continuity of outside work and the efficiency of the workmen. The strength of the storm winds must be known by those concerned in the erection of buildings and other structures. The humidity of the atmosphere has in recent years become recognized as a very important factor in many manufacturing establishments, especially in the silk, rayon and cement industries. A great variety of court cases require exact evidence of weather conditions on certain specified days to determine whether accidents should be attributed to negligence of certain individuals or to unusual weather over which the defendants had no control. The insurance companies are increasing their business of insuring against rain on days of special celebrations or on the occasion of athletic contests and desire unbiased accurate observations on the particular dates. No longer is farming the only industry dependent on the weather. Instead, the application of science to almost all industries has brought about a definite recognition of the almost universal importance of weather. This has led to the efforts to control various weather elements in order to achieve greater human efficiency and improve the quality of manufactured products. Of course, air conditioning can not be applied to most of the heavy industries, desirable though it may be, and therefore many concerns must find locations where favorable natural conditions prevail. Numerous requests for information concerning Lehigh Valley weather and climate have been received from companies seeking new locations.

It may be well to distinquish between weather and climate as the two are frequently confused. Briefly, weather is the combination of all of the meteorological elements—atmospheric pressure, temperature,

precipitation, wind, etc.—at some particular time; whereas, climate is the average conditions based on observations over considerable time. The distinction has been expressed in the statement that "weather is a passing phase of climate."

In general, the current ideas of climate and weather are woefully inaccurate, based as they are on inaccurate observations and on faulty recollections of the inhabitants, who almost invariably recall the unusual events and forget the normal occurrences. The belief in former colder winters and greater snow falls is almost universal among old people in any community, regardless of the fact that over and over again it has been shown by instrumental readings and carefully recorded observations of trained meteorologists that there is little or no basis for such conclusions. An examination of the data presented in the following pages should disprove the common belief in definite trends in any one direction sufficient for one to forecast conditions in succeeding seasons. It is doubtful also whether anyone will be able to note recurring cycles of the elements which make up our climate and weather.

The most valuable studies of weather and climate must be based on statistics. Meteorological conditions that have occurred at one time may recur, and when many years are involved the reasonable assumption is that all types of weather that may ever be expected will be represented. For such studies the longer the records the more dependable are the conclusions. Each year is different and yet the variations from the average are seldom marked.

Reliable meteorological records have been kept in the Lehigh Valley for many years. With few exceptions, in this report only those of Lehigh and Northampton counties are mentioned, although observations taken in the adjoining counties of Berks, Bucks and Carbon are available. The weather elements noted, and the length of time when each observer served, are given in the table below as far as the records are preserved. Nearly all the observations were taken either wholly or in part with instruments furnished by the U. S. Weather Bureau, and most of the original records are preserved in the Philadelphia office of that organization. Duplicate records are on file also at the respective stations. Much of the available data is contained in the publications of the U. S. Weather Bureau, mainly in the monthly reports and annual summaries of Climatological Data, Pennsylvania Section, which are preserved in many libraries.

All the observational data used were taken according to the regulations of the U. S. Weather Bureau. These observations are frequently greatly at variance with those given by local papers and passed about by word of mouth. The extreme temperatures of summer are

almost invariably lower than those recorded by the ordinary themometers on the street level or where they are not properly shielded from the direct rays of the sun. In the winter extremes, likewise, these records are apt to be higher than those recorded by poor or improperly placed themometers. The miscellaneous precipitation data of untrained observers are more reliable than temperature records but they too may be inaccurate and therefore such information has been ignored in the preparation of this report, even though a mass of meteorological data might be collected from the files of newspapers and other publications of the Lehigh Valley.

In the discussion of the weather and climate of any locality many different elements or factors are worthy of consideration. Obviously, in a volume of this character, it is impossible to treat more than a few of these, even where records are available. The ones selected are maximum, minimum and mean temperatures, frost, precipitation (both rain and snow), relative humidity, winds, and descriptions of storms that pass through the Lehigh Valley.

List of official meteorological observations in Lehigh and Northampton Counties

Duration	Elements	Observer
	Allentown	
Jan. 1912-Dec. 1920	Monthly precipitation.	?
Mar. 1922 to date	Temperature — maximum, minimum, etc., precipitation, prevailing wind direction, character of day.	John A. Frick
	Bethlehem (North Side)	
July 1877-Dec. 1895	Precipitation.	?
Jan. 1896-Oct. 1898	Precipitation.	J. Edw. Luckenbach
Nov. 1898-Apr. 1902 Lacking: Feb., Nov. 1899 Aug., Oct. 1900 Feb., June 1901	Precipitation.	Jas. E. Krause
	Bethlehem (South Side)	
Jan. 1896-May 1899 Jan. 1900-June 1900 Jan. 1901-Mar. 1901	Maximum and minimum temperature, prevailing wind direction, character of day.	C. W. Bachert
Aug. 1901-Sept. 1901	Maximum and minimum temperature, precipitation.	R. M. Merriman
Oct. 1901-Aug. 1903	Maximum and minimum temperature, precipitation, prevailing wind direction, character of day.	R. M. Merriman Mansfield Merriman Norman Merriman

List of official meteorological observations in Lehigh and Northampton Counties—Continued

Duration	Elements	Observer
	Bethlehem (North Side)	
Feb. 1910-May 1913 June 1913-May 1922 June 1922-May 1923 June 1923-May 1925 June 1925-Nov. 1925	Maximum and minimum temperature, precipitation, snowfall, prevailing wind direction, character of day.	Edward C. Roest Chas. H. Rominger E. E. McColm Robt. H. Brennecke, Jr. Louis P. Harlacher
	Bethlehem (South Side)	
Dec. 1925-May 1926	Maximum and minimum temperature, precipitation, snowfall, prevailing wind direction, character of day.	Lehigh University R. W. Baker H. A. Brown
June 1926-Sept. 1926	" " "	Lehigh University Robert F. Riley
Oct. 1926-May 1927	" " "	R. W. Baker H. A. Brown
June 1927-Mar. 1928	" " "	John H. Schumacher
Apr. 1928 to date	" " "	P. E. Rodgers
	Coopersburg	
Jan. 1890-Dec. 1900	Monthly mean temperature and precipitation.	?
	Easton	
Feb. 1856-Dec. 1859	Precipitation.	Geo. R. Houghton
Jan. 1883-Dec. 1895	Precipitation.	J. W. Moore
Jan. 1896-July 1903 Aug. 1903-July 1909 Aug. 1909-Oct. 1909	Maximum and minimum temperature, etc., precipitation, character of day.	J. W. Moore George R. Miller J. W. Colliton
Nov. 1927 to date	Maximum and minimum temperature, etc., precipitation.	Lafayette College H. A. Itter
	North Whitehall and Egypt	
Jan. 1856-Apr. 1881	Monthly mean temperature.	? Made for the Smithsonian Institution.

Maximum Temperatures

Records of maximum temperatures taken at Allentown, Bethlehem, and Easton are available for a number of years, enough to afford a fairly accurate picture of average conditions. An examination of the tables below will show that the highest temperature recorded at Allentown was 103° F. in July 1936, 105° F. at Bethlehem in August 1918, and 103° F. at Easton in 1936. The temperature of the three localities should be almost identical although occasionally subject to common local, summer variations. The highest temperatures are experienced in July most commonly although in certain years the hottest days fall in August or June, occasionally in September and May. In 1915 the highest temperature of the year in many places in eastern Pennsylvania was registered on April 25.

Minimum Temperatures

Minimum temperatures for Allentown, Bethlehem and Easton are available for a number of years. As far as recorded by the observers working in cooperation with the U. S. Weather Bureau, the lowest temperature for Allentown was 12° F. in February 1934, for Bethlehem, 16° F. in January 1912, and for Easton, 16° F. in February 1934. No doubt both Allentown and Easton experienced lower temperatures in January 1912, which was an extremely cold month in the Lehigh Valley, but at that time no observers were located in either place.

Mean Temperatures

For purposes of comparison mean temperatures are perhaps more important than the maximum and minimum temperatures given later. The mean daily temperature, as given in the official records of the U. S. Weather Bureau, is the average of the daily maximum and the daily minimum, and the mean monthly temperature is the average of the mean daily temperatures of the month. The mean annual temperature similarly is the average of the mean monthly temperatures.

Mean monthly temperatures are available for periods of years for Allentown, Bethlehem, Coopersburg, Easton and North Whitehall and Egypt.

Maximum temperature at Allentown

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Highest Temperature of Year
1922	—	—	—	—	—	—	—	—	—	—	64	55	
1923	50	43	73	87	86	100	98	92	88	72	61	62	100 June 20
1924	—	—	68	76	87	91	94	100	95	82	73	63	100 August 6
1925	45	62	74	86	95	100	96	93	90	74	65	56	100 June 6
1926	57	50	69	79	86	88	101	95	90	86	70	46	101 July 22
1927	45	56	77	88	82	95	97	84	95	92	74	61	97 July 13
1928	58	53	75	82	90	90	94	95	88	86	76	60	95 August 4
1929	62	56	75	90	94	95	96	96	96	74	75	58	96 July 28, Aug. 1, Sept. 3
1930	65	74	72	73	94	93	101	98	91	79	66	48	101 July 21
1931	54	54	58	75	91	97	97	95	95	84	73	63	97 June 20, July 1
1932	71	59	59	77	90	90	92	94	97	80	60	64	97 September 1
1933	56	57	59	81	86	98	99	97	87	80	69	53	99 July 31
1934	54	49	67	75	92	99	95	88	84	72	74	65	99 June 29
1935	52	54	76	87	89	92	95	94	84	83	75	55	95 July 12
1936	44	47	74	84	93	95	103	96	90	78	76	61	103 July 9
1937	66	59	61	81	92	95	97	95	94	78	67	58	97 July 8
Average	55.6	55.2	69.1	81.4	89.8	94.5	97.0	94.2	91.5	79.9	69.9	58.0	
Highest temperature of month	71	74	77	90	95	100	103	100	97	92	76	65	

Minimum temperature at Allentown

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Lowest Temperature of Year
1922	—	—	—	—	—	—	—	—	36	28	25	13	
1923	5	7	11	12	34	51	55	47	38	30	23	19	5 January 30
1924	—	7	18	25	35	43	52	49	40	30	11	10	
1925	—6	10	8	28	30	48	51	49	38	22	23	9	—6 January 28
1926	2	10	12	25	33	43	51	53	45	31	21	3	2 January 29
1927	0	19	20	28	35	43	51	42	40	36	26	15	0 January 27
1928	—5	6	18	28	37	45	53	52	36	27	22	14	—5 January 30
1929	6	5	12	32	35	41	47	50	40	30	10	10	5 February 23
1930	—1	3	16	21	40	42	51	45	44	26	11	9	—1 January 20
1931	12	10	23	29	30	47	57	54	39	32	25	18	10 February 1, 3
1932	23	14	10	27	40	39	52	52	34	30	12	3	3 December 19
1933	13	—3	15	28	39	40	46	51	42	25	12	—2	—3 February 13
1934	1	—12	—5	29	35	52	53	41	43	30	23	12	—12 February 9
1935	—7	—6	14	29	35	50	57	48	38	30	24	8	—7 January 28
1936	—5	—2	14	27	35	47	51	51	36	21	18	9	—5 January 23, 24
1937	19	13	18	29	36	50	55	54	38	25	25	11	11 December 11
Average	4.1	5.4	13.6	26.5	35.3	45.4	52.1	49.2	39.2	28.3	19.4	10.1	
Lowest temperature of month	—7	—12	—5	12	30	39	46	41	34	21	10	—2	

Maximum temperature at Bethlehem

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Highest Temperature of Year
1896	59	62	65	91	92	89	91	98	85	69	73	54	98 August 9
1897	56	52	63	85	80	88	96	89	93	88	72	59	96 July 11
1898	49	56	75	78	88	93	102	92	96	85	76	62	102 July 3
1899	49	56	62	74	88	—	—	—	—	—	—	—	
1900	—	58	54	76	92	88	—	—	—	—	—	—	
1901	—	39	59	—	—	—	—	88	84	74	58	64	
1902	51	52	73	88	90	92	90	87	71	63	71	37	92 June 13
1903	49	67	72	87	91	84	93	88	—	—	—	—	93 July 10
1910	—	55	86	84	84	91	96	88	91	85	61	51	96 July 9, 24
1911	52	56	72	82	94	92	100	96	87	76	70	66	100 July 3
1912	46	53	67	79	86	94	96	93	90	83	70	61	96 July 9
1913	61	60	76	85	90	94	98	98	89	82	71	65	98 July 30, August 6
1914	55	50	74	83	94	92	94	94	92	83	70	64	94 May 27, August 9, 19
1915	61	62	60	94	78	88	92	93	93	82	73	58	94 April 25
1916	71	65	69	78	85	84	93	101	92	87	72	66	101 August 22
1917	53	55	70	84	89	87	98	96	85	78	66	47	98 July 31
1918	51	57	81	78	89	93	95	105	84	79	67	60	105 August 7
1919	59	55	70	84	91	97	99	91	92	88	73	48	99 July 4, 5
1920	44	50	73	80	85	94	90	92	88	87	68	63	94 June 10, 28
1921	56	67	84	83	89	97	104	95	93	79	79	59	104 July 4
1922	48	70	77	86	96	90	92	94	96	91	66	55	96 May 31, September 6, 7
1923	56	48	74	88	85	97	90	92	90	—	—	63	97 June 25
1924	60	46	68	78	—	89	93	99	96	81	—	63	99 August 6
1925	46	66	75	86	94	98	93	93	90	74	68	56	98 June 4
1926	58	50	67	77	86	86	98	98	90	85	70	43	98 July 21, 22, August 11
1927	47	58	75	86	81	94	95	84	93	89	74	66	95 July 31
1928	57	54	72	79	89	88	93	93	87	87	76	59	93 July 8, August 4, 5
1929	61	55	76	88	94	96	96	96	96	76	74	60	96 June 18, July 28, Aug. 1, Sept. 2, 3
1930	68	75	72	74	94	94	100	98	93	84	65	52	100 July 21, 22
1931	54	56	61	75	92	97	98	96	97	86	75	65	98 July 1
1932	72	60	61	78	90	92	92	97	101	81	61	65	101 September 1
1933	58	57	60	81	86	100	101	98	89	82	76	63	101 July 31
1934	55	48	69	78	93	100	96	90	86	77	75	60	100 June 29, 30
1935	54	56	78	86	87	91	94	94	84	78	74	55	94 July 11, 12, August 13
1936	44	50	75	84	96	94	104	97	90	81	75	63	104 July 9
1937	66	62	61	82	93	95	99	98	93	79	68	59	99 July 10, 11
Average	55.3	56.6	70.1	82.2	89.1	92.3	95.9	94.1	90.2	81.0	70.5	58.5	
Highest temperature of month	72	75	86	94	94	100	104	105	101	89	79	66	

Minimum temperature at Bethlehem

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Lowest Temperature of Year
1896	2	—8	6	28	46	58	64	56	45	34	26	4	—8 February 17
1897	3	16	24	24	39	40	59	55	40	33	22	10	3 January 26
1898	6	1	20	20	34	53	49	55	44	38	22	6	1 February 2
1899	—3	—9	22	28	40	—	—	—	—	—	—	--	—9 February 10
1900	—	24	10	32	44	61	—	—	—	—	—	--	
1901	—	14	8	—	—	—	—	58	40	32	18	8	
1902	11	6	17	30	37	47	55	50	54	46	26	21	6 February 6
1903	5	—1	26	26	30	46	47	47	—	—	—	—	—1 February 18, 19
1910	—	0	22	31	38	44	54	49	45	26	21	4	0 February 7
1911	12	14	12	23	35	49	56	51	33	30	18	16	12 January 5, 18, March 16
1912	—16	—5	10	25	39	44	51	50	38	36	26	5	—16 January 14
1913	18	8	11	30	34	42	55	50	40	34	28	15	8 February 14
1914	—4	0	15	26	37	47	55	52	35	33	22	0	—4 January 14
1915	10	14	20	30	39	46	55	—	45	28	29	10	10 January 30, December 12
1916	2	—3	5	31	42	46	55	51	38	28	19	8	—3 February 15
1917	—3	—4	6	27	32	47	53	50	43	28	18	—9	—9 December 31
1918	—2	—8	15	28	39	46	48	53	43	32	22	20	—8 February 5
1919	7	16	20	20	41	48	60	58	42	31	26	—6	—6 December 18
1920	2	—6	12	23	34	51	54	53	38	32	21	15	—6 February 1
1921	1	5	21	25	39	46	59	48	38	19	18	—2	—2 December 22
1922	—5	—4	30	31	37	50	61	58	46	47	28	12	—5 January 17, 26
1923	2	5	10	11	35	49	50	47	40	33	23	20	2 January 31
1924	1	9	19	25	—	44	54	49	31	31	16	9	1 January 22
1925	—8	8	8	28	32	50	52	47	39	22	23	7	—8 January 28
1926	1	11	11	24	36	45	60	61	47	29	23	7	1 January 29
1927	—2	13	19	22	41	48	52	49	41	37	25	14	—2 January 27
1928	4	5	18	28	40	48	54	55	38	28	21	15	4 January 30
1929	5	13	10	34	38	44	50	51	40	30	10	13	5 January 14
1930	2	5	16	29	42	48	54	48	43	29	12	10	2 January 19, 20
1931	12	10	24	31	33	54	59	55	44	35	27	18	10 February 3
1932	23	15	10	28	40	43	54	55	38	33	12	7	7 December 19
1933	12	2	15	30	42	43	48	55	48	28	13	—3	—3 December 29
1934	5	—13	10	29	37	50	54	43	44	31	25	12	—13 February 9
1935	—3	—1	18	28	40	52	56	49	38	31	23	8	—3 January 28
1936	—5	0	15	28	36	50	55	54	39	22	17	10	—5 January 23
1937	18	14	16	31	41	51	53	55	41	28	26	14	14 February 4, December 12
Average	3.4	4.6	15.3	27.0	37.9	47.9	54.4	52.0	41.1	31.3	21.4	9.0	
Lowest temperature of month	—16	—13	5	20	32	42	48	43	31	19	10	—9	

Maximum temperature at Easton

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Highest Temperature of Year
1896	47	57	61	89	90	90	91	96	86	68	68	51	96 August 7
1897	55	47	66	82	80	88	94	88	90	83	64	61	94 July 6, 10
1898	52	52	71	73	86	92	98	90	93	83	62	53	98 July 3
1899	50	53	65	80	86	95	91	93	83	74	62	62	95 June 6
1900	53	59	53	77	91	90	97	93	87	81	71	51	97 July 17
1901	48	48	55	83	83	94	99	90	87	74	58	62	99 July 1, 2
1902	48	52	71	84	89	90	91	86	85	72	67	56	91 July 9
1903	47	65	68	84	91	84	94	90	84	76	67	51	94 July 10
1904	53	45	62	76	90	95	94	86	86	78	58	47	95 June 26
1905	50	44	76	76	85	96	97	90	82	80	63	56	97 July 18
1906	66	50	55	78	89	91	91	92	86	74	59	53	92 August 6
1907	58	45	80	75	84	89	91	88	84	74	58	58	91 July 18
1908	51	60	74	80	88	94	96	93	83	80	60	62	96 July 12
1909	55	59	62	83	87	92	92	94	80	75	—	—	94 August 9
1927	—	—	—	—	—	—	—	—	—	—	73	67	
1928	53	52	76	81	90	90	96	97	87	88	66	52	97 August 5
1929	64	58	78	90	86	95	98	96	98	75	75	58	98 July 29, September 5
1930	69	74	72	75	94	93	100	98	91	79	66	47	100 July 21
1931	55	48	61	76	95	98	99	98	96	84	73	60	99 July 2
1932	70	60	59	78	91	92	94	94	98	78	66	62	98 September 2
1933	50	54	55	79	89	101	102	99	87	78	68	52	102 July 31
1934	55	48	66	77	93	97	97	97	85	73	72	61	97 June 29, July 26, August 11, 24
1935	48	56	76	88	88	92	96	95	83	77	75	54	96 July 12
1936	42	47	72	82	92	95	103	97	90	78	78	62	103 July 9
1937	68	59	60	82	93	96	99	94	92	76	66	55	99 July 10
Average	54.8	56.2	66.4	80.3	88.8	92.9	95.9	93.1	87.6	77.5	67.6	56.4	
Highest temperature of month	70	74	80	90	95	98	103	98	98	88	78	67	

Minimum temperature at Easton

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Lowest Temperature of Year
1896	—1	—8	2	23	44	46	55	48	37	29	24	0	—8 February 17
1897	1	2	16	22	39	44	60	52	40	30	17	8	1 January 26
1898	6	2	22	18	31	46	48	53	43	30	20	7	2 February 2, 4
1899	—3	—12	17	25	41	47	50	49	40	25	23	3	—12 February 10
1900	3	0	0	26	33	51	51	53	40	27	23	8	0 February 2, March 18
1901	2	8	9	33	39	48	57	56	41	30	18	4	2 January 20
1902	10	5	16	30	37	46	52	48	38	28	26	7	5 February 6
1903	5	—2	25	25	31	47	48	47	36	29	17	5	—2 February 19
1904	—9	—2	12	24	41	41	51	45	33	25	18	2	—9 January 5, 6
1905	—1	—1	9	25	34	45	52	50	36	30	17	15	—1 January 26, 31, February 16
1906	5	1	9	29	35	48	56	56	44	28	23	6	1 February 6
1907	—1	—1	0	21	32	43	50	50	40	27	23	17	—1 January 24, 27, February 12
1908	2	—2	17	23	38	46	51	49	41	30	6	15	—2 February 5
1909	—1	6	7	23	35	47	49	48	38	26	—	—	—1 January 19
1927	—	—	—	—	—	—	—	—	—	—	27	13	
1928	0	5	16	27	40	51	53	56	38	29	30	12	0 January 31
1929	5	9	10	33	40	43	50	52	40	30	9	9	5 January 14
1930	2	3	16	27	40	40	47	45	44	26	11	10	2 January 19
1931	11	7	23	31	33	50	59	55	44	34	24	15	7 February 7
1932	20	13	9	27	34	40	52	54	36	30	8	3	3 December 19
1933	10	—1	11	30	38	42	45	55	46	24	12	—5	—5 December 29
1934	2	—16	8	28	42	51	54	43	43	28	21	6	—16 February 9
1935	—5	—3	14	29	40	52	60	49	39	32	23	0	—5 January 28
1936	—9	—4	12	26	34	49	51	54	37	22	15	8	—9 January 23
1937	16	10	15	32	39	52	54	55	38	27	26	12	10 February 4
Average	2.9	0.8	12.3	26.5	37.1	46.5	52.4	50.9	39.7	28.2	19.2	7.5	
Lowest temperature of month	—9	—16	0	18	31	40	45	43	33	24	6	—5	

Monthly and annual mean temperatures at Allentown

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1922	—	—	40.6	51.4	64.8	72.0	73.5	—	—	—	43.3	31.2	—
1923	27.5	24.4	35.2	49.0	59.7	74.2	73.8	71.4	66.1	51.8	40.6	—	—
1924	—	27.2	37.8	47.6	56.8	67.4	73.1	72.2	62.2	54.4	40.6	30.2	—
1925	23.6	34.4	41.0	50.0	57.4	74.8	72.1	71.4	67.5	47.4	40.5	32.4	51.0
1926	28.6	28.3	33.6	46.6	60.6	65.6	74.0	72.8	63.8	—	40.8	26.8	—
1927	27.8	34.4	41.8	48.2	57.8	65.4	73.4	66.8	65.4	56.5	45.5	34.4	51.4
1928	31.9	30.1	36.9	47.0	58.9	66.2	74.8	73.8	61.2	54.4	43.8	35.1	51.2
1929	28.4	29.2	43.6	51.0	59.8	69.9	73.6	69.8	66.8	50.7	42.6	30.5	51.3
1930	27.8	32.6	38.5	47.2	61.9	71.0	74.0	71.2	68.1	50.8	41.2	30.6	51.2
1931	29.3	30.9	37.6	49.1	59.8	68.3	75.6	72.0	69.4	56.4	48.9	37.6	52.9
1932	40.6	33.6	34.4	46.8	59.6	68.2	72.5	72.4	65.4	54.2	38.9	32.8	51.6
1933	35.6	29.3	36.3	50.0	62.0	70.2	72.9	71.4	66.0	51.4	37.6	30.0	51.0
1934	30.3	16.4	33.6	48.2	61.3	71.8	74.8	68.4	65.4	51.2	45.0	31.2	49.8
1935	25.3	27.6	40.4	48.6	57.5	69.4	75.8	71.6	61.4	55.0	46.8	28.2	50.6
1936	24.5	21.6	44.0	46.9	63.8	70.0	75.8	74.6	66.6	54.4	39.8	35.8	51.5
1937	36.2	32.8	35.6	48.8	63.2	71.6	74.8	75.4	63.8	52.4	43.2	32.0	52.5
Average	29.8	28.8	38.2	48.5	60.3	69.7	74.0	71.7	65.3	52.9	42.4	31.9	51.3

Monthly and annual mean temperatures at Coopersburg

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1890	37.8	37.2	34.9	50.0	59.8	70.0	70.4	68.8	62.9	53.3	41.7	28.2	51.2
1891	32.1	35.5	35.0	51.7	58.5	69.3	68.1	69.9	66.5	50.6	39.7	39.8	51.4
1892	27.0	32.5	32.7	48.2	59.3	70.8	73.0	71.3	62.4	51.5	39.8	—	—
1893	20.2	27.8	34.8	47.7	58.7	68.3	72.0	71.5	60.4	53.2	39.8	32.2	48.9
1894	34.0	28.6	43.8	49.4	60.8	69.9	74.8	70.5	66.8	54.3	39.4	34.1	52.2
1895	27.0	24.0	35.4	49.4	60.7	71.2	70.0	74.3	68.4	48.6	44.8	36.8	50.9
1896	30.6	32.4	34.5	53.8	65.5	67.6	74.3	73.0	66.0	52.2	49.1	34.2	52.8
1897	29.8	34.5	41.4	50.8	59.8	65.3	73.8	70.4	66.4	56.4	44.8	37.4	52.6
1898	34.4	35.0	47.8	47.8	59.5	72.8	77.2	74.3	69.0	57.2	43.8	33.6	54.4
1899	29.4	27.1	39.2	50.4	60.6	71.3	73.2	71.6	63.2	55.8	45.0	36.4	51.9
1900	32.6	31.0	35.4	51.6	60.4	71.0	75.6	74.8	68.6	60.0	47.2	34.2	53.5
Average	30.4	31.4	37.7	50.1	60.3	69.8	72.9	71.9	65.5	53.9	43.2	35.1	51.8

Monthly and annual mean temperature at Bethlehem

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1896	29.0	32.5	36.7	57.8	71.4	73.5	77.0	73.7	66.4	54.4	47.2	31.4	54.2
1897	29.0	35.0	39.7	50.2	59.5	66.4	76.3	72.6	66.6	56.6	44.6	34.0	52.5
1898	31.8	31.0	49.0	49.2	61.7	75.9	76.8	75.2	68.2	60.4	45.0	27.8	54.3
1899	27.3	25.0	37.8	48.5	64.6	—	—	—	—	—	—	—	—
1900	—	30.0	36.1	54.6	64.8	74.1	—	—	—	—	—	—	—
1901	—	27.3	39.2	—	—	—	—	72.6	64.6	52.3	36.8	30.6	—
1902	26.5	25.8	42.7	50.6	61.0	68.2	73.1	69.0	62.6	54.1	48.8	29.0	51.2
1903	28.0	32.4	47.6	51.0	63.3	64.5	72.2	66.8	—	—	—	—	—
1910	—	29.7	46.0	53.6	61.0	67.3	75.9	72.4	69.2	57.4	—	26.2	—
1911	33.0	31.4	39.0	48.8	70.0	71.2	79.2	75.1	67.2	54.0	40.0	37.4	53.9
1912	20.0	26.5	35.6	52.2	62.4	68.4	74.2	71.2	68.0	59.4	47.2	36.9	51.8
1913	41.4	31.5	46.6	53.9	61.1	70.9	75.0	—	—	59.6	47.0	38.4	—
1914	32.4	25.9	38.4	—	64.9	69.6	—	74.2	—	—	44.6	30.6	—
1915	33.6	36.8	38.6	57.8	59.6	68.7	74.8	—	70.3	59.1	—	32.8	—
1916	35.8	28.5	33.4	51.1	63.2	65.6	76.8	75.2	65.8	54.9	43.0	31.6	52.1
1917	30.6	28.4	38.8	52.0	54.4	68.4	74.0	75.0	66.2	53.4	42.3	24.9	50.7
1918	19.2	30.3	44.3	51.0	67.0	—	73.4	75.5	63.2	59.4	44.2	38.1	—
1919	33.9	35.2	45.2	51.2	62.0	72.6	—	72.4	69.8	63.6	45.8	28.8	—
1920	24.6	29.4	40.8	49.6	59.4	69.6	—	—	67.5	61.2	42.6	35.8	—
1921	34.0	34.6	50.4	57.6	61.4	72.0	77.5	69.6	69.5	51.4	40.8	29.4	54.0
1922	23.6	37.2	—	—	—	—	—	—	—	—	—	—	—
1923	31.7	—	40.0	—	61.8	73.6	—	—	68.2	—	—	42.0	—
1924	33.2	29.6	39.1	48.3	—	67.4	72.8	73.2	62.4	56.1	—	33.0	—
1925	26.5	36.9	44.7	53.6	58.6	74.8	72.6	72.2	69.0	50.6	44.0	33.0	53.0
1926	30.8	29.8	35.7	47.0	62.0	67.0	—	—	67.2	53.9	43.2	28.6	—
1927	29.0	36.8	43.9	48.0	59.1	66.8	74.3	67.6	66.0	57.2	48.8	35.8	52.8
1928	32.2	31.7	38.6	49.4	60.6	67.8	75.8	75.4	64.1	58.0	46.7	37.5	53.2
1929	30.2	32.4	46.2	53.3	61.6	71.6	74.9	71.4	68.6	54.0	45.6	32.8	53.6
1930	31.7	36.4	41.8	49.4	64.6	73.0	76.2	73.7	69.6	54.8	44.4	33.0	54.0
1931	32.0	33.1	39.8	51.7	63.1	72.2	77.9	74.6	71.9	59.4	51.4	40.0	55.6
1932	42.6	36.9	36.8	49.9	62.2	70.6	75.0	75.1	68.5	56.8	42.4	36.0	54.4
1933	39.0	33.7	38.6	52.8	64.5	73.7	75.0	73.9	68.8	55.0	40.5	31.4	53.8
1934	33.2	20.6	37.8	51.8	64.6	74.2	76.9	71.0	68.2	53.8	48.0	32.6	52.7
1935	28.2	30.8	44.5	50.0	58.8	70.2	76.8	73.8	63.9	56.6	48.4	28.9	52.5
1936	26.2	24.6	46.2	48.4	66.3	71.2	77.6	76.0	69.0	56.6	41.0	36.6	53.3
1937	38.0	34.8	36.0	50.4	64.9	73.2	76.4	76.6	65.6	54.0	44.8	33.4	54.0
Average	30.8	31.2	41.0	51.4	62.6	70.4	72.9	73.0	67.2	56.3	44.6	33.1	53.2

Monthly and annual mean temperatures at Easton

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1896	26.6	29.9	31.0	53.6	66.0	68.6	74.8	72.5	64.2	49.6	45.8	30.1	51.06
1897	27.6	31.1	39.0	50.1	61.2	66.2	74.4	70.0	63.7	54.4	42.2	33.8	51.14
1898	31.6	31.3	45.2	48.2	60.2	70.8	76.2	73.4	67.0	54.6	40.8	31.3	52.55
1899	26.6	24.4	37.5	50.4	62.2	72.4	74.0	72.6	63.6	55.2	42.7	34.1	51.31
1900	30.0	29.6	35.2	50.8	61.4	71.6	76.1	75.4	69.2	59.0	45.5	31.6	52.95
1901	29.8	23.7	38.4	49.0	60.4	70.8	78.4	74.2	66.2	52.9	36.3	30.1	50.85
1902	26.6	26.4	43.2	51.0	61.2	68.6	73.0	68.6	63.3	53.8	47.4	28.0	50.92
1903	27.6	31.5	46.8	49.8	62.8	64.4	72.4	67.4	63.8	54.2	39.8	27.4	50.65
1904	21.2	23.1	36.3	46.3	64.0	69.6	72.6	69.4	63.8	50.4	39.2	24.6	48.37
1905	25.5	22.5	38.8	50.2	62.6	69.2	75.4	70.8	64.7	53.7	40.6	34.6	50.71
1906	35.3	29.2	33.4	51.5	62.6	71.2	74.0	74.4	68.0	54.1	42.0	31.6	52.3
1907	30.4	23.2	41.0	45.4	56.2	65.7	74.0	70.4	65.8	48.8	42.2	35.4	49.9
1908	31.6	27.3	41.6	50.6	62.0	70.8	75.9	70.7	65.7	55.3	41.6	33.4	52.2
1909	31.8	37.2	37.8	49.9	60.8	70.7	71.8	69.4	63.6	50.3	—	—	54.33
1927	—	—	—	—	—	—	—	—	—	—	46.1	33.2	—
1928	31.2	29.4	37.7	46.6	60.0	71.8	75.7	75.6	65.5	57.9	45.7	36.4	51.9
1929	30.4	31.0	45.9	49.7	61.7	72.2	75.5	72.0	71.0	52.6	43.8	30.5	53.0
1930	28.7	30.2	38.6	46.8	61.9	71.4	72.0	70.5	66.0	50.8	41.3	31.3	50.3
1931	29.0	33.8	37.2	49.5	61.5	69.7	77.6	73.1	70.1	57.4	49.1	35.8	53.6
1932	39.0	33.5	33.1	46.6	60.3	67.2	74.6	73.0	66.1	52.7	36.7	32.8	51.3
1933	34.2	29.0	35.1	50.5	61.6	71.8	74.4	72.2	65.9	50.0	35.9	28.5	50.76
1934	30.1	17.3	34.5	47.7	61.4	71.2	75.4	69.9	67.4	49.8	43.6	26.7	49.5
1935	25.5	28.4	40.6	48.3	58.1	71.2	78.5	72.8	62.5	55.6	46.5	25.2	51.1
1936	22.9	20.3	43.0	45.5	63.0	69.1	75.1	73.9	65.6	55.9	39.4	35.9	50.8
1937	36.1	29.7	33.6	48.8	64.0	72.1	75.5	75.7	63.0	51.6	42.5	30.8	51.95
Average	29.6	28.0	38.5	49.0	61.5	69.9	75.3	72.0	65.6	53.4	42.4	31.4	51.29

Monthly and annual mean temperatures at North Whitehall and Egypt

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1856	19.9	23.2	28.7	49.5	56.5	67.4	74.8	68.9	64.0	50.1	41.4	29.4	47.8
1857	18.3	35.2	34.7	41.4	57.3	65.4	72.9	70.9	62.7	52.7	41.3	36.4	49.1
1858	35.5	25.8	37.4	49.3	56.4	72.8	75.5	70.7	62.9	56.1	38.2	32.4	51.1
1859	29.9	32.6	43.9	47.3	62.8	66.4	71.5	70.3	61.7	48.8	42.6	28.1	50.5
1860	24.4	27.6	40.3	45.4	61.2	67.4	72.0	71.7	61.7	54.7	44.0	29.1	50.4
1861	27.9	33.3	38.3	49.6	53.4	68.9	71.6	71.4	64.5	66.8	40.6	34.8	51.1
1862	29.8	28.9	35.1	46.7	60.0	64.4	71.5	71.5	66.3	53.6	40.1	32.8	50.1
1863	32.0	30.2	30.8	47.0	62.3	63.1	73.3	73.8	60.0	51.9	43.0	31.3	50.2
1864	28.6	31.8	36.6	48.4	66.6	66.6	73.2	74.6	61.1	50.5	41.6	31.9	51.9
1865	21.7	28.2	43.3	53.0	60.8	72.6	71.7	69.6	68.1	49.6	41.3	32.7	51.1
1866	25.6	29.5	35.2	51.8	55.3	67.8	75.2	63.2	64.1	63.1	41.9	28.5	48.5
1867	21.2	34.7	34.6	49.7	54.4	67.6	71.5	70.5	63.2	52.1	42.4	27.3	49.1
1868	24.4	21.5	36.5	43.5	57.1	67.8	77.5	72.7	63.4	48.2	42.0	27.9	48.5
1869	32.1	32.3	34.1	49.2	57.8	68.2	71.7	71.0	64.5	48.5	37.2	32.9	50.0
1870	34.7	30.4	33.3	51.4	63.3	74.0	78.1	74.1	67.1	54.5	46.5	31.5	52.8
1871	27.7	29.8	42.6	52.1	61.7	69.1	71.6	74.5	60.1	52.5	37.6	27.1	50.6
1872	27.4	—	30.6	50.0	63.6	71.6	77.0	75.6	65.9	50.4	37.8	—	—
1873	24.8	26.9	33.1	45.8	58.4	69.9	75.3	71.0	64.0	61.2	34.3	33.3	49.0
1874	—	30.5	37.1	40.2	59.6	71.5	73.5	69.5	67.2	52.2	39.1	30.1	—
1875	22.1	19.4	30.1	42.4	61.7	69.8	74.1	71.8	62.8	50.2	36.6	31.5	47.7
1876	32.9	31.6	34.2	44.0	60.9	73.5	77.5	—	—	48.9	43.2	22.2	—
1877	24.6	33.8	34.1	50.1	60.8	72.2	75.9	—	66.3	56.2	44.0	39.0	—
1878	30.6	34.6	45.9	57.2	60.5	67.9	76.7	75.6	67.1	55.8	42.7	31.7	53.7
1879	24.0	26.2	38.6	48.4	63.9	71.3	75.9	71.7	63.0	60.6	42.1	35.0	51.7
1880	37.4	30.9	37.7	51.3	70.1	74.2	74.9	75.2	67.7	64.0	37.4	27.2	53.5
1881	24.7	29.1	38.4	48.7	—	—	—	—	—	—	—	—	—
Average	27.5	29.7	36.5	48.5	60.2	71.0	75.0	72.2	64.8	52.8	39.9	30.6	50.8

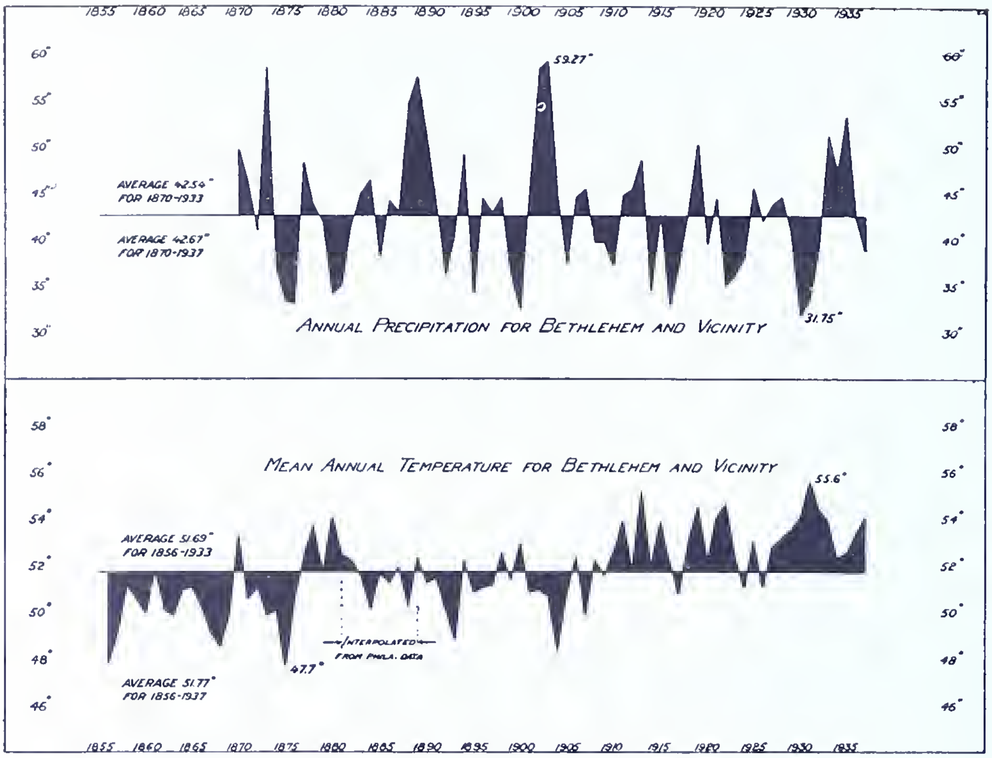


Figure 1.

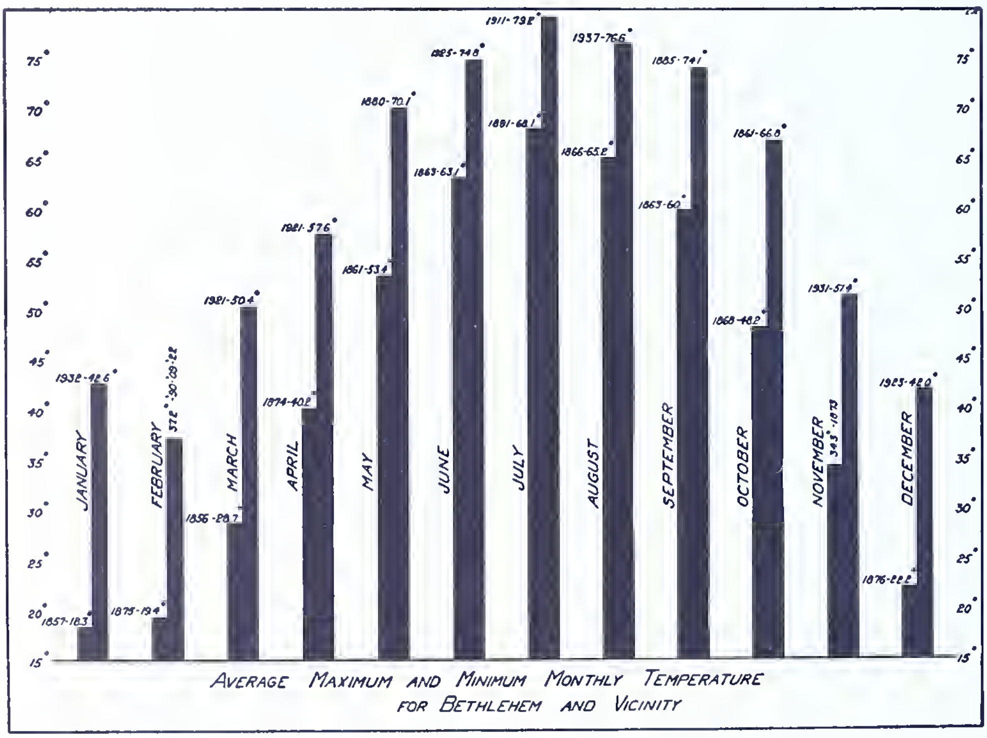


Figure 2.

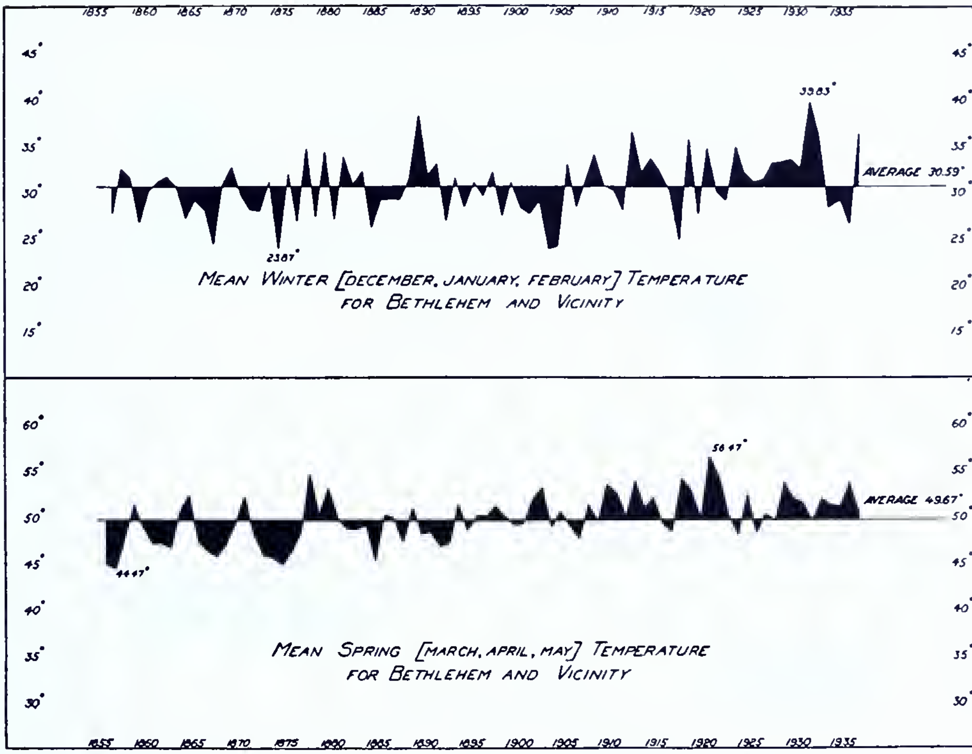


Figure 3.

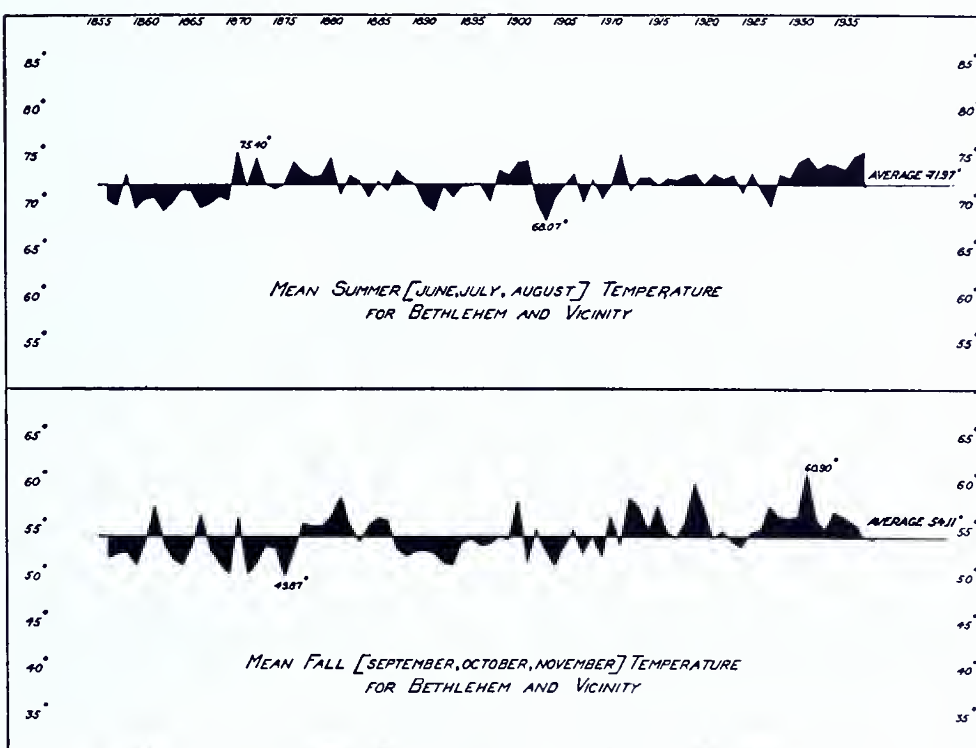
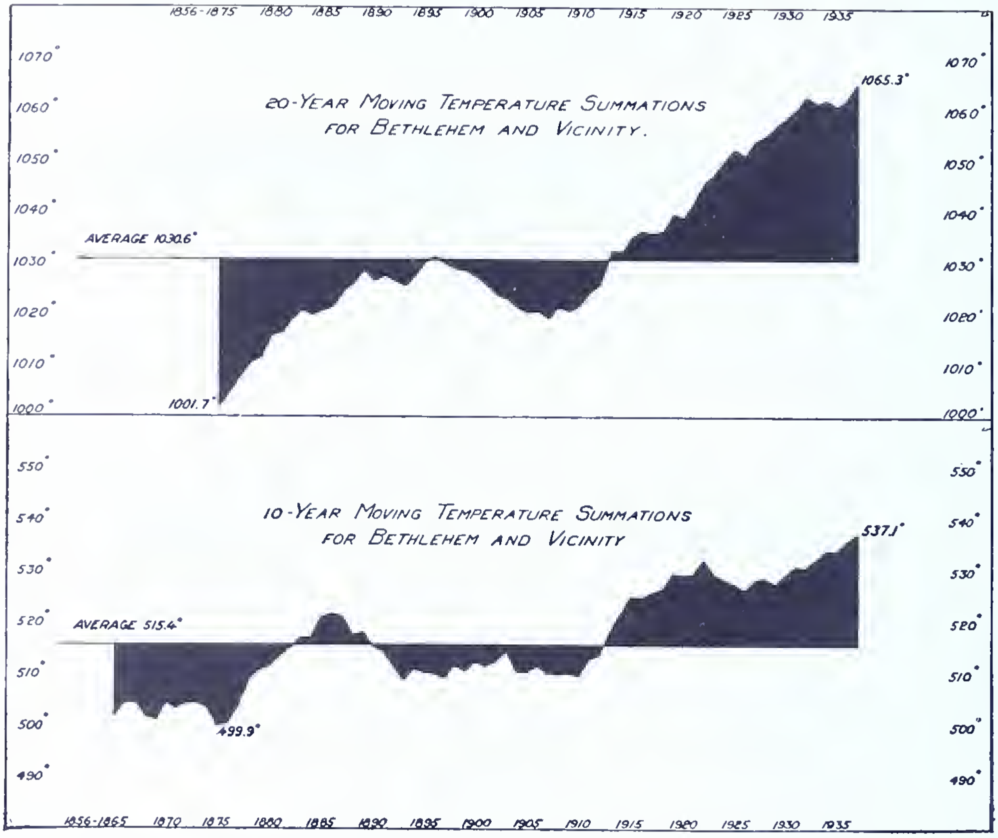


Figure 4.



See note on page 93.

Figure 5.

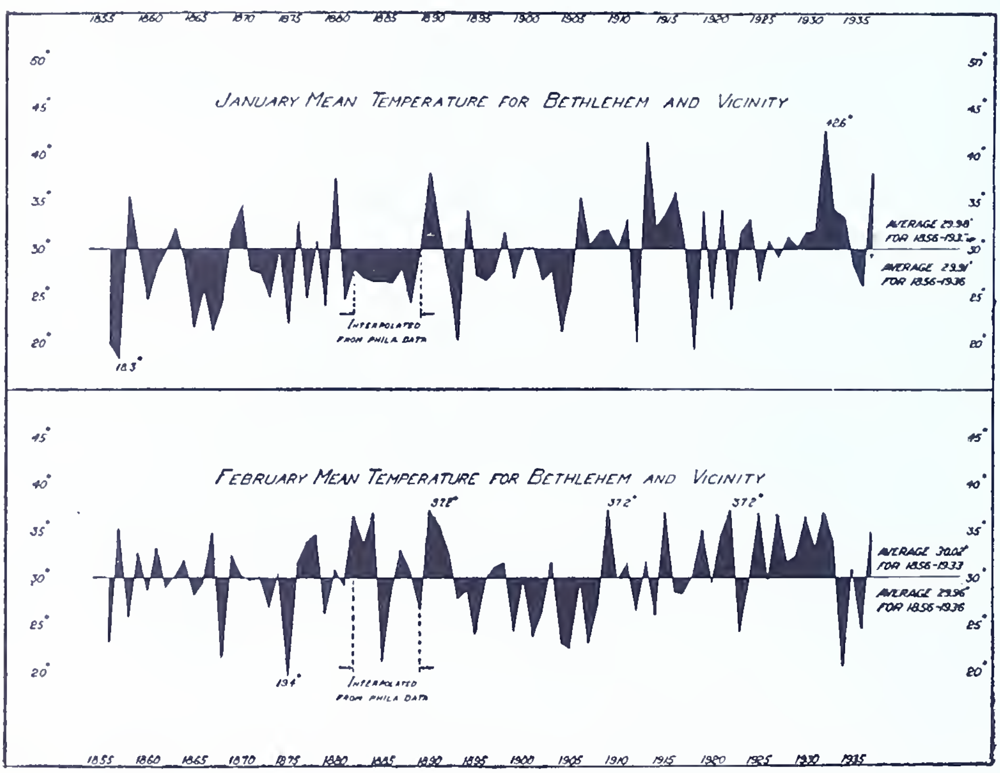


Figure 6.

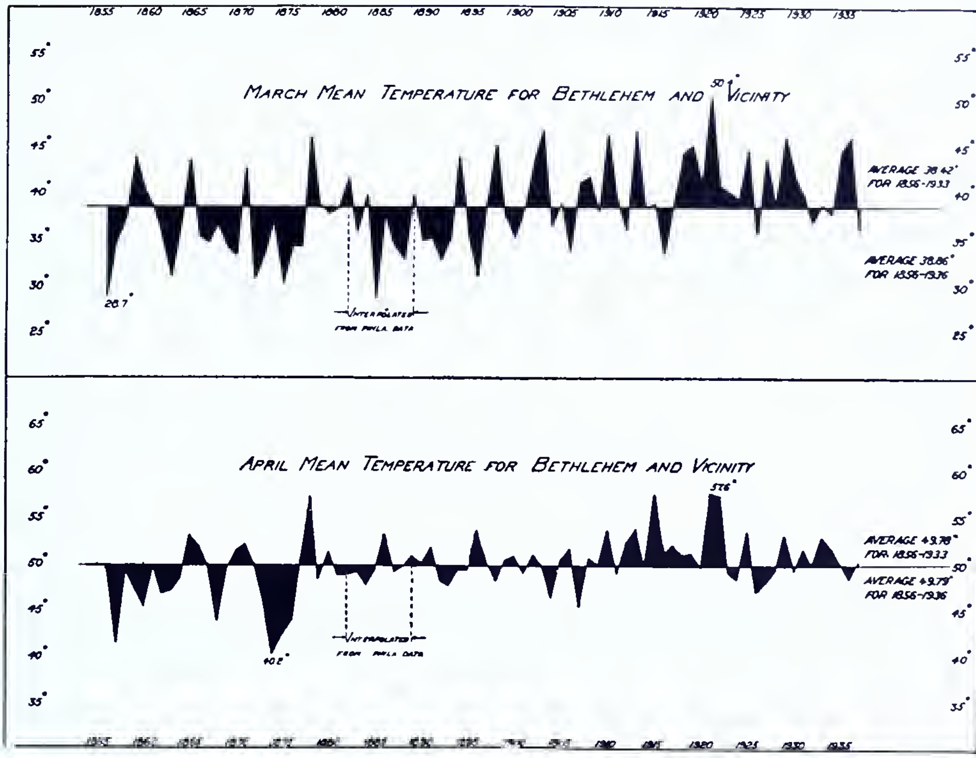


Figure 7.

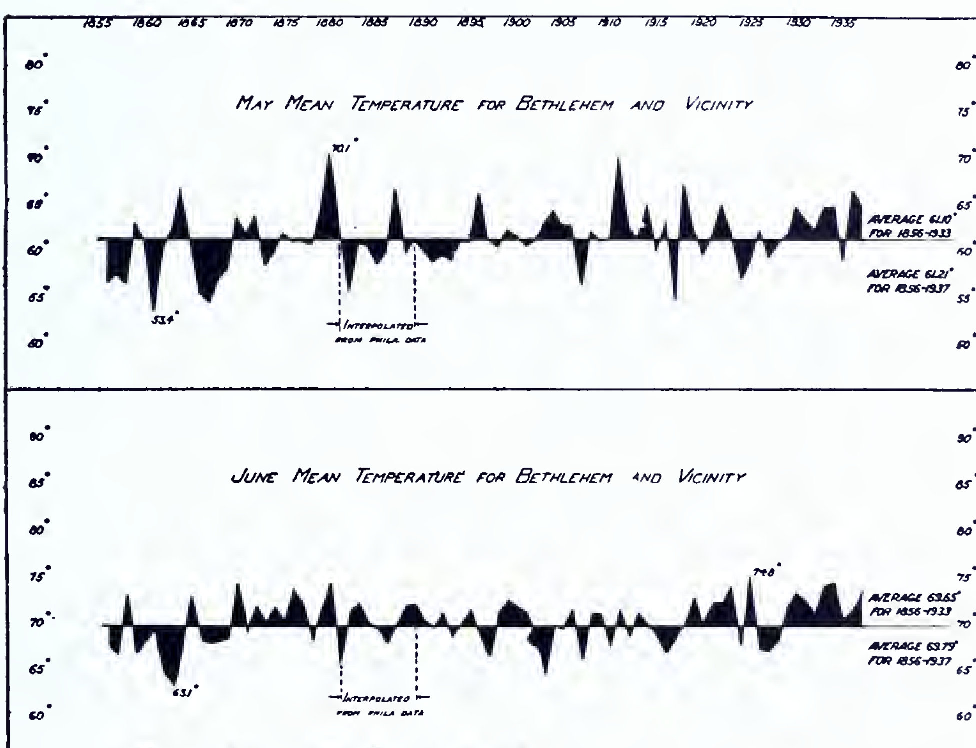


Figure 8.

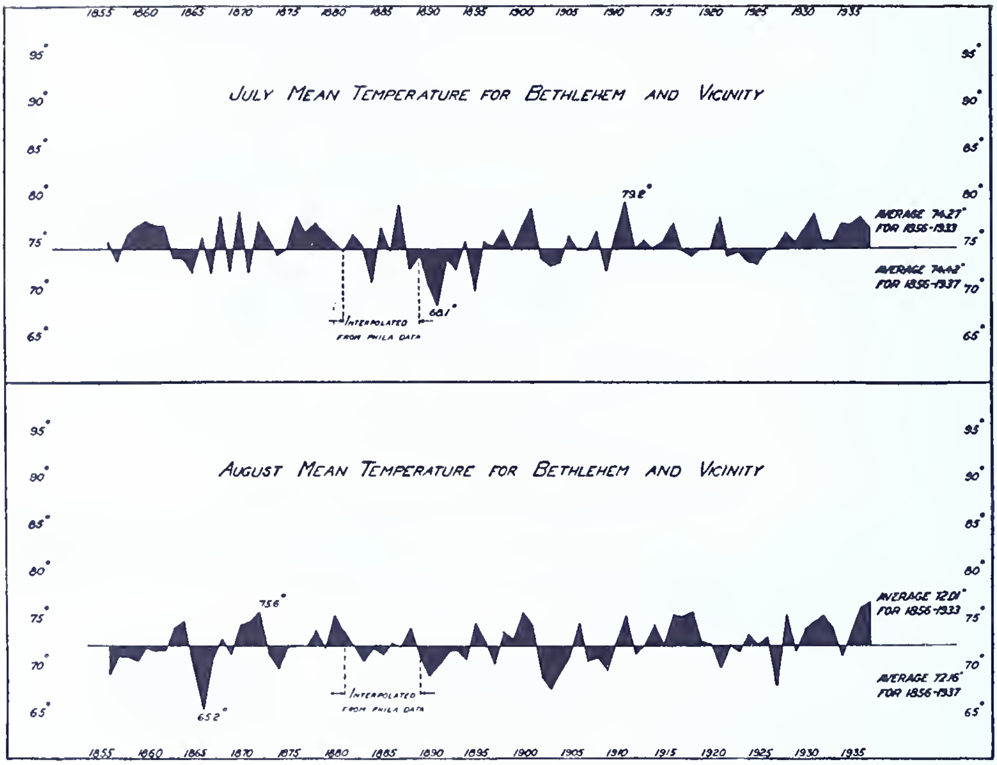


Figure 9.

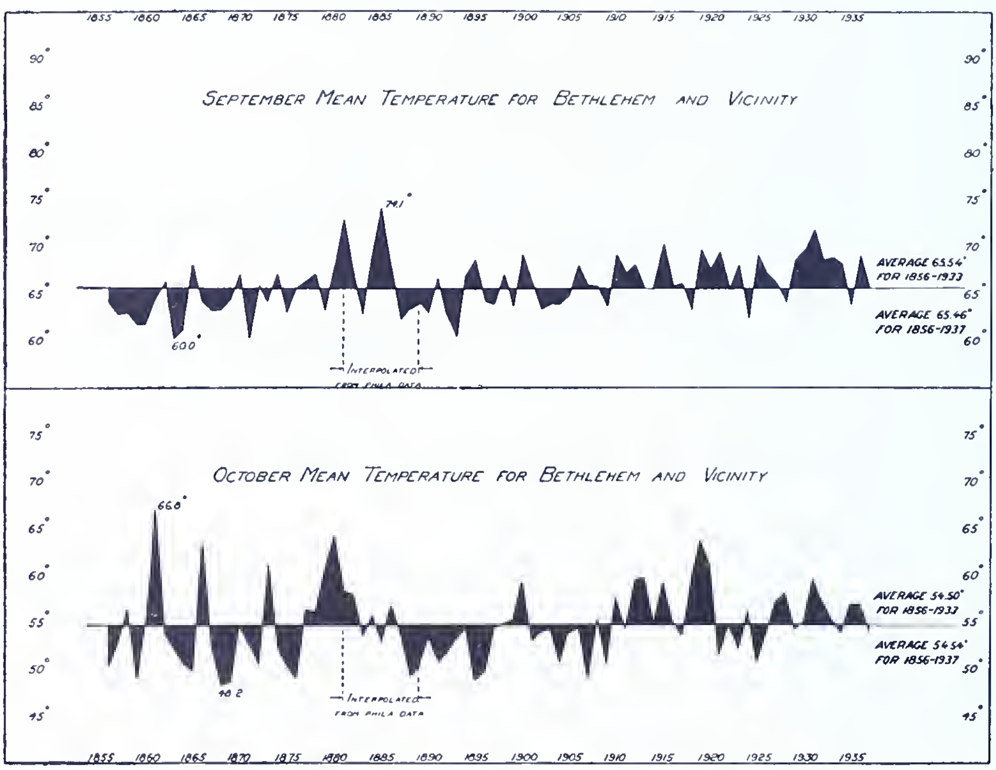


Figure 10.

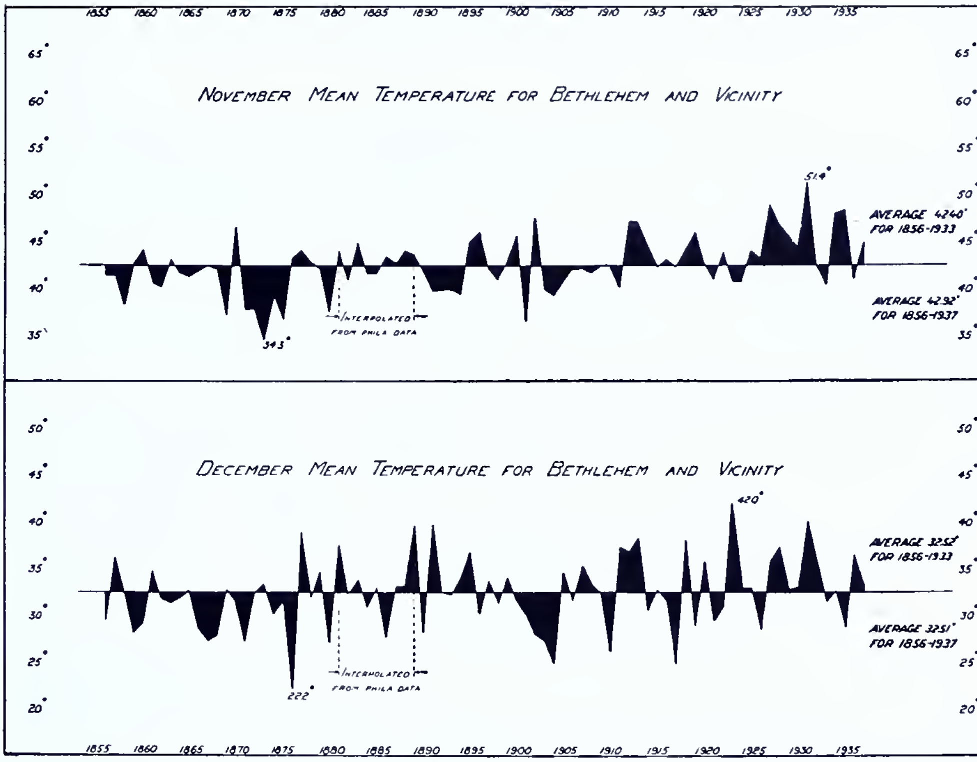


Figure 11.

Note regarding figures 5 and 25:

Moving summations are prepared by adding the values for the first 10 or 20 years for the first point on the graph. The next point is obtained by dropping the first year of data and adding the 11th and 21st. This process is continued for successive points. Moving summations furnish evidence of general trends.

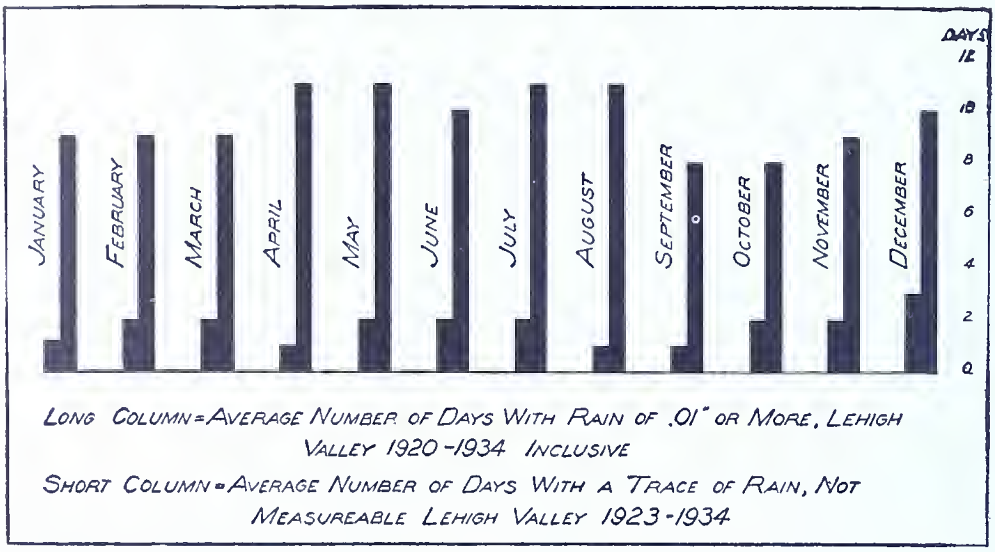


Figure 12

Killing Frost

Closely connected with the temperatures discussed above are the first killing frost in the autumn and the last one in the spring, as they determine the harvesting and planting of many plants. Naturally, there will be difference of opinion as to the exact dates owing to the fact that some plants are killed by temperatures that scarcely affect others and that vegetation in the lowlands may be killed on a cold night without material injury to equally susceptible plants growing on uplands.

It should also be recognized that killing frosts may occur without the official thermometers registering 32° F., for they always are placed in shelters some feet above the ground or on the tops of buildings. The ground temperature may be and usually is several degrees lower than that recorded in the instrument shelters.

Generalizing for the Lehigh Valley it may be said that the average date of the first killing frost in the autumn is about October 16 or 17, although it may occur in the latter part of September or as late as the first week in November. The average date of the last killing frost in the spring is about April 18, although it may be March 18 or as late as the middle of May. Light frost has been reported in favorable places during June and also in August. The average growing season for the section is therefore almost exactly six months or half of the year.

Precipitation

Ranking with temperature in importance is precipitation, including both rain and snow. Frost, dew and fog are of some effect, but they are not measurable.

Precipitation at Allentown

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1912	3.25	2.48	5.85	3.37	4.32	2.71	2.85	5.10	7.43	3.31	3.17	3.59	47.43
1913	3.94	2.09	7.24	6.82	2.60	2.00	3.64	4.10	3.97	5.80	2.79	4.07	49.06
1914	3.93	4.53	2.03	3.74	2.96	2.48	5.20	2.92	0.28	1.61	2.01	5.53	37.25
1915	6.03	5.74	1.00	2.70	3.76	2.15	4.34	11.19	3.65	4.02	2.07	4.82	51.47
1916	1.94	3.09	4.01	3.31	2.20	4.71	9.88	0.81	3.58	1.82	2.30	3.96	41.61
1917	3.70	1.45	4.54	1.90	2.27	5.47	5.27	4.08	2.88	5.87	0.65	2.58	40.66
1918	5.15	2.36	2.04	4.89	3.96	3.04	2.57	4.20	2.91	1.02	1.65	3.75	37.54
1919	2.50	2.05	5.13	2.34	8.07	4.76	7.61	2.67	2.29	5.60	3.10	1.98	48.10
1920	2.45	3.59	—	5.51	2.48	3.61	4.05	4.07	3.16	1.65	3.87	4.38	—
1922	—	—	4.60	3.23	4.33	4.57	4.08	4.24	1.87	1.47	0.47	2.13	—
1923	5.11	2.34	3.68	3.14	3.01	0.61	2.46	2.40	3.63	4.57	2.11	5.35	38.49
1924	5.14	4.26	1.46	4.79	5.07	4.85	3.80	3.73	5.00	1.66	2.50	2.12	44.38
1925	5.80	2.08	2.75	1.62	3.56	2.50	5.98	4.54	4.12	5.64	3.17	2.32	44.08
1926	2.29	4.54	1.81	2.26	2.31	3.41	7.04	5.85	4.23	4.48	5.46	2.75	46.43
1927	2.56	3.03	1.44	3.18	3.55	5.53	3.04	7.49	1.64	6.84	3.88	6.54	48.72
1928	2.61	4.19	2.76	5.34	2.50	5.49	6.68	9.95	2.22	0.62	1.54	1.42	45.32
1929	3.39	3.25	2.54	7.31	2.66	3.29	1.83	4.10	5.09	4.67	3.19	2.86	44.18
1930	2.24	2.36	2.27	2.86	3.85	2.65	4.74	1.71	1.45	0.97	1.76	2.79	29.65
1931	2.04	2.15	2.99	1.79	3.01	5.81	8.92	3.00	1.65	2.44	0.43	2.11	36.34
1932	3.42	1.57	4.53	2.22	4.73	2.30	2.09	3.17	0.95	5.40	7.05	2.21	39.64
1933	1.73	3.16	4.96	4.71	6.11	2.51	5.61	11.00	5.94	1.96	0.72	1.82	50.23
1934	2.69	1.48	2.60	4.08	4.57	5.00	3.97	4.17	10.19	1.82	3.05	3.60	47.22
1935	2.63	2.20	2.63	2.70	1.04	4.55	7.91	4.15	5.13	3.50	5.62	1.61	43.67
1936	6.48	2.80	5.97	3.04	2.87	6.10	1.14	3.96	0.87	3.84	1.47	5.31	43.85
1937	5.47	2.41	2.36	4.10	2.81	3.65	5.46	6.58	0.91	3.73	2.02	1.61	41.11
Average	3.60	2.88	3.59	3.63	3.54	3.75	4.80	4.76	3.40	3.37	2.64	3.25	43.32

Maximum and minimum precipitation by months and year of occurrence

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Maximum:													
Inches	6.48	5.74	7.24	7.31	8.07	6.10	9.88	11.19	10.19	6.84	7.05	6.54	51.47
Year	1936	1915	1913	1929	1919	1936	1916	1915	1934	1927	1932	1927	1915
Minimum:													
Inches	1.73	1.45	1.00	1.62	1.04	0.61	1.14	0.81	0.28	0.62	0.43	1.42	29.65
Year	1933	1917	1915	1925	1935	1923	1936	1916	1914	1928	1931	1928	1930

Precipitation at Bethlehem

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1877	—	—	—	—	—	—	6.50	6.64	3.23	6.31	5.40	1.60	—
1878	4.52	3.25	2.75	2.92	4.65	3.50	5.28	2.03	2.49	3.40	3.44	5.60	43.83
1879	—	1.23	3.41	3.98	2.17	8.38	4.04	6.03	1.90	0.81	1.84	5.54	—
1880	2.95	2.86	4.13	3.50	1.26	3.88	4.17	2.50	2.47	1.85	2.73	1.71	34.01
1881	4.06	2.43	5.48	0.99	2.87	6.08	1.36	0.59	0.90	2.90	2.72	4.61	34.99
1882	3.32	3.90	4.91	2.19	6.58	3.28	2.77	3.54	5.25	2.70	1.32	1.62	41.38
1883	4.32	4.04	2.71	2.79	2.88	8.62	4.52	1.55	4.20	5.16	1.54	2.59	44.92
1884	2.38	4.85	5.04	2.41	2.86	4.76	8.13	2.49	1.03	3.64	2.71	6.05	46.35
1885	4.43	3.65	1.04	2.36	2.29	1.05	2.76	9.17	0.54	4.92	4.28	1.60	38.09
1886	3.63	4.68	4.08	2.98	5.59	4.52	3.53	2.15	1.76	2.19	5.44	3.66	44.21
1887	3.62	5.46	1.86	2.08	1.96	5.70	8.58	3.46	2.78	1.12	1.32	5.11	43.05
1888	5.08	3.50	3.84	3.30	2.84	3.12	2.64	9.20	10.93	2.77	3.82	3.60	54.64
1889	4.66	1.94	3.35	4.30	4.30	5.28	9.93	4.10	6.14	3.30	8.72	1.66	57.68
1890	2.28	4.43	6.12	2.58	7.44	3.10	6.02	5.92	3.51	6.17	0.82	2.98	51.37
1891	5.62	3.88	5.38	1.96	2.29	2.44	5.80	5.45	2.53	2.66	1.89	4.11	44.01
1892	5.76	0.62	4.67	0.70	4.40	3.89	1.37	3.33	2.54	0.44	6.70	1.60	36.02
1893	2.79	6.41	2.57	3.38	4.59	2.97	1.88	4.61	2.14	2.79	3.51	2.47	40.11
1894	1.54	4.50	1.29	2.41	10.80	2.49	2.83	2.07	8.54	5.04	2.86	4.85	49.22
1895	4.04	0.89	2.31	4.46	2.33	4.48	3.84	2.96	0.63	3.69	1.66	2.61	33.90
1896	1.26	6.41	5.82	1.27	6.30	3.60	6.13	2.22	3.68	2.77	4.32	0.70	44.48
1897	2.35	2.57	2.50	3.41	6.05	4.03	4.84	3.64	2.10	1.22	5.99	4.22	42.92
1898	4.35	3.17	2.79	3.37	6.05	1.05	4.47	5.23	0.90	4.44	5.23	3.50	44.55
1899	3.65	2.11	4.06	1.70	1.76	3.10	3.08	4.83	7.31	1.15	—	1.37	—
1900	2.54	4.13	—	—	—	2.43	5.11	—	1.22	—	—	2.03	—
1901	—	—	4.94	4.42	4.56	—	3.66	8.75	3.08	2.62	1.64	6.57	—
1902	3.07	6.89	5.03	3.37	1.07	6.75	4.10	5.82	6.32	5.90	1.64	8.39	58.35
1903	5.03	5.49	4.87	4.59	0.45	11.76	7.85	4.88	—	—	—	—	—
1910	—	5.36	0.83	5.74	2.78	3.37	0.45	2.78	5.54	2.04	2.73	2.29	—
1911	2.93	1.66	2.93	3.42	1.55	7.77	2.88	6.77	1.85	7.23	2.93	2.81	44.73
1912	1.16	2.44	6.83	3.67	4.20	2.58	2.72	4.94	5.96	3.68	2.47	4.77	45.42
1913	4.22	2.13	6.41	6.28	3.33	1.80	2.50	5.01	4.29	5.41	3.05	4.04	48.58
1914	3.87	2.62	2.30	—	2.51	3.01	4.58	2.91	—	1.47	1.63	5.47	—
1915	5.74	4.74	1.15	2.41	3.27	1.94	2.90	9.20	3.03	3.17	1.75	3.13	42.43
1916	1.79	2.11	3.69	3.12	2.07	4.01	6.36	1.17	2.94	0.76	1.73	3.16	32.91
1917	4.24	1.95	4.79	1.28	3.03	5.89	4.46	1.39	1.42	5.37	0.68	2.60	37.10
1918	4.45	2.67	1.30	6.98	6.05	3.42	5.28	3.16	2.94	0.64	2.21	4.07	43.17
1919	3.44	3.18	4.63	1.28	4.50	3.25	10.21	5.79	2.39	4.46	4.65	2.43	50.21
1920	2.58	—	1.06	4.53	2.35	2.84	5.63	3.46	3.59	2.05	3.48	4.32	—
1921	3.07	3.30	2.31	4.63	3.30	3.80	6.11	3.15	5.12	1.79	5.46	2.34	44.38
1922	2.72	2.64	4.31	—	3.63	5.34	—	2.60	1.96	1.60	0.53	2.29	—
1923	3.99	2.43	3.87	—	2.74	0.41	3.15	2.48	4.10	4.13	—	3.58	—
1924	4.13	3.76	1.14	4.29	4.40	3.26	2.36	—	6.38	0.00	2.26	2.22	—

Precipitation at Bethlehem—Concluded

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1925	6.12	2.36	2.88	2.58	3.42	2.32	7.80	4.12	3.26	5.53	2.86	2.34	45.59
1926	1.97	2.47	1.72	1.84	2.22	3.44	5.39	5.63	4.54	6.29	4.79	1.65	41.95
1927	2.51	1.94	1.30	1.96	3.33	4.54	3.88	6.01	1.03	5.66	5.28	6.33	43.77
1928	3.15	4.42	3.32	5.20	2.55	5.74	5.39	9.72	2.21	0.45	1.54	0.87	44.56
1929	3.19	3.73	2.44	5.23	2.66	3.90	2.24	3.70	3.92	4.35	3.09	2.44	40.89
1930	2.01	2.16	2.50	2.99	2.13	2.96	6.46	1.27	1.61	1.82	3.08	2.76	31.75
1931	1.81	1.72	2.73	1.92	3.19	5.15	6.22	3.3	2.34	2.51	0.71	1.83	33.44
1932	3.55	1.77	4.63	1.52	4.19	2.32	2.02	2.92	0.89	5.92	7.01	2.37	39.11
1933	1.68	3.45	4.88	5.17	7.78	1.74	5.26	10.27	5.97	2.32	0.73	2.00	51.25
1934	2.94	1.82	3.45	3.36	3.61	5.53	3.62	3.72	10.80	1.85	4.17	2.80	47.67
1935	3.02	2.12	3.17	2.19	0.86	4.84	11.97	3.23	4.44	6.13	7.05	1.63	50.65
1936	6.07	2.58	6.36	3.49	2.58	5.67	1.17	3.28	1.03	3.11	1.40	5.56	42.30
1937	5.37	1.85	2.12	3.95	3.13	3.14	5.73	5.89	0.75	3.15	1.79	1.72	38.59
Average	3.52	3.20	3.47	3.21	3.57	4.04	4.66	4.36	3.38	3.26	3.15	3.22	43.38

Maximum and minimum precipitation at Bethlehem by months and year of occurrence

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Maximum:													
Inches	6.12	6.89	6.83	6.98	10.80	11.76	11.97	10.27	10.93	7.23	8.72	8.39	58.35
Year	1925	1902	1912	1918	1894	1903	1935	1933	1888	1911	1889	1902	1902
Minimum:													
Inches	1.16	0.62	0.83	0.70	0.45	0.41	0.45	0.59	0.54	0.00	0.53	0.70	31.72
Year	1912	1892	1910	1892	1903	1923	1910	1881	1885	1924	1922	1896	1930

Precipitation at Easton

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1856	—	0.72	—	2.93	3.46	2.36	1.48	6.44	6.51	0.96	2.48	3.25	—
1857	3.32	1.70	1.04	5.74	7.34	5.76	3.94	3.46	1.07	3.15	1.48	5.26	43.26
1858	2.26	1.05	0.69	3.12	6.60	4.45	4.15	2.68	2.69	1.82	4.84	4.22	38.57
1859	3.76	3.35	6.89	4.98	2.15	4.10	4.09	5.01	6.93	2.23	3.61	4.56	51.66
1883	3.20	3.87	2.40	2.94	2.68	4.62	4.86	2.36	4.27	5.22	1.61	3.36	41.39
1884	4.73	4.77	4.97	2.38	2.28	2.87	5.19	5.91	1.01	3.96	3.26	6.07	47.40
1885	4.74	4.18	0.77	2.40	2.29	2.74	2.63	7.76	0.59	5.37	4.03	3.30	40.80
1886	3.08	5.28	4.11	3.37	7.14	3.93	4.65	2.63	1.33	2.37	5.80	3.86	47.55
1887	3.01	5.79	3.34	2.25	3.96	6.10	11.28	4.30	3.24	1.41	1.55	6.01	52.24
1888	6.45	3.91	3.95	3.96	3.18	1.49	2.83	9.39	11.75	2.97	3.79	4.17	57.84
1889	5.36	2.26	3.61	5.21	6.08	3.77	10.48	5.27	6.40	4.51	9.90	1.12	63.97
1890	1.99	3.75	6.39	3.42	5.98	4.72	5.79	6.00	3.23	5.65	1.26	3.38	51.55
1891	6.42	3.74	5.02	2.41	2.78	3.22	4.48	5.13	1.85	3.42	1.77	4.77	45.01
1892	5.30	1.08	3.84	1.70	4.53	4.57	2.38	3.70	2.73	0.54	6.06	1.62	38.05
1893	3.56	6.46	3.10	3.86	4.82	1.66	3.51	5.29	2.92	2.62	3.21	3.24	44.25
1894	1.88	3.39	1.25	1.90	8.70	2.54	0.53	2.04	6.57	5.47	2.70	3.55	40.52
1895	3.56	1.55	2.16	3.91	2.58	3.10	5.02	2.29	0.74	4.62	2.22	2.47	34.22
1896	1.03	6.24	3.99	1.23	4.41	3.98	10.28	3.47	4.49	2.38	4.46	0.49	46.45
1897	1.92	1.28	0.82	1.20	5.75	3.26	8.04	3.20	2.49	1.85	6.20	5.63	41.64
1898	4.71	3.70	3.07	3.25	8.03	1.90	4.89	5.06	1.18	5.64	6.22	3.12	50.77
1899	4.03	3.41	4.41	1.92	2.51	3.90	2.89	5.87	6.14	0.82	2.32	2.04	40.26
1900	3.72	5.78	3.18	1.63	2.50	2.27	6.83	3.55	1.72	1.60	2.51	2.32	37.61
1901	2.14	0.71	5.44	4.39	5.89	2.29	3.11	6.96	2.71	1.19	1.53	6.90	43.26
1902	2.49	5.80	3.37	3.35	2.22	6.50	4.52	3.65	8.31	5.35	1.26	7.22	54.04
1903	4.13	4.23	4.44	4.38	0.77	9.15	6.65	5.42	1.43	7.96	1.34	3.62	53.52
1904	3.06	1.53	3.22	3.35	3.00	3.25	4.40	9.64	4.92	3.57	1.88	2.79	44.61
1905	4.70	1.16	3.89	1.90	1.05	2.34	3.21	5.14	4.64	4.18	2.52	2.71	37.44
1906	2.70	2.33	4.34	3.92	4.51	4.94	3.98	3.93	2.39	5.17	1.25	5.06	44.52
1907	3.40	2.15	2.83	3.42	2.79	3.84	1.01	3.14	8.68	4.28	5.46	4.44	45.44
1908	2.81	5.63	2.97	2.75	6.43	2.30	4.81	3.97	2.30	2.52	0.70	2.51	39.70
1909	3.72	6.01	3.02	6.01	2.82	3.77	3.02	1.51	3.07	1.04	—	—	—
1927	—	—	—	—	—	—	—	—	—	—	5.69	5.56	—
1928	2.55	4.57	2.93	4.84	2.85	6.63	7.83	10.52	2.18	0.97	2.29	1.06	49.22
1929	4.41	3.15	3.31	7.91	3.38	4.03	2.53	4.43	5.12	4.75	3.70	2.98	49.70
1930	2.71	2.59	2.96	3.54	2.72	3.44	5.41	1.83	1.90	2.14	3.43	3.26	35.93
1931	2.14	1.92	3.08	2.21	3.29	9.71	8.34	2.79	2.29	2.96	0.90	2.05	41.68
1932	4.52	2.25	5.45	1.68	6.22	3.28	2.85	3.43	1.33	7.98	8.01	2.90	49.90
1933	1.41	3.27	6.07	5.97	5.93	2.31	2.89	13.58	7.41	1.91	0.87	3.62	55.24
1934	3.67	2.33	4.77	3.61	3.74	3.78	3.11	3.83	10.42	1.90	3.29	2.79	46.94
1935	3.15	2.05	2.85	1.62	0.87	3.80	9.28	3.23	4.63	5.73	6.92	1.69	45.84
1936	6.54	2.59	7.05	3.50	2.69	5.95	1.25	3.34	1.72	2.26	1.34	6.50	44.73
1937	5.63	2.14	2.58	3.74	2.77	4.52	5.10	7.43	0.71	4.37	2.55	1.74	43.28
Average	3.56	3.18	3.43	3.36	3.99	3.97	4.72	4.84	3.80	3.38	3.32	3.59	45.64

Precipitation at Coopersburg

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1890	2.88	5.32	7.92	3.21	7.93	3.14	5.53	6.72	4.18	6.04	0.95	3.76	57.58
1891	7.29	4.57	6.54	2.50	2.25	2.33	6.07	7.16	2.04	2.74	2.27	4.83	50.59
1892	6.98	1.05	4.77	1.58	5.12	4.42	3.48	4.05	3.56	0.60	6.78	1.78	44.17
1893	4.26	6.50	2.53	4.07	5.42	2.86	1.96	6.22	3.23	3.26	3.89	2.64	46.84
1894	1.69	4.26	1.60	3.18	14.78	2.58	2.65	2.43	5.86	5.62	2.75	5.04	52.44
1895	4.19	1.71	2.60	5.40	3.08	2.40	4.00	3.29	0.75	4.08	2.32	3.22	37.04
1896	1.13	6.88	5.43	1.35	4.15	3.45	8.46	0.66	6.08	3.29	4.87	1.04	46.79
1897	2.62	3.73	2.77	3.59	8.74	4.33	6.48	2.92	2.07	2.65	6.80	4.76	51.46
1898	4.41	3.82	2.55	3.98	7.05	1.04	2.70	5.03	0.91	6.05	7.22	3.78	48.54
1899	4.73	5.15	6.82	1.85	3.14	3.17	4.53	4.88	7.25	1.48	2.20	1.69	46.89
1900	3.31	5.48	3.70	1.94	2.72	1.35	6.76	2.33	1.86	2.20	2.12	2.59	36.36
Average	3.95	4.41	4.29	2.97	5.85	2.82	4.78	4.15	3.44	3.46	3.83	3.11	47.06

Maximum and minimum precipitation at Easton by months and year of occurrence

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Maximum:													
Inches	6.54	6.46	7.05	7.91	8.70	9.71	13.58	10.52	11.75	7.98	9.90	7.22	63.97
Year	1936	1893	1936	1929	1894	1931	1933	1928	1888	1932	1889	1902	1889
Minimum:													
Inches	1.03	0.71	0.69	1.20	0.77	1.49	0.53	1.51	0.59	0.54	0.70	0.49	34.22
Year	1896	1901	1858	1897	1903	1888	1894	1909	1885	1892	1908	1896	1895

Precipitation at North Whitehall and Egypt

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1874	—	3.00	1.50	4.95	2.05	3.70	2.85	3.35	3.00	4.08	2.15	2.57	—
1875	1.89	1.70	4.45	1.35	1.00	2.07	1.15	8.55	1.90	4.35	—	1.95	—
1876	0.70	3.88	4.80	0.40	2.45	2.00	3.60	1.20	6.60	1.35	4.50	1.50	32.98
1877	1.85	1.35	5.60	2.70	1.40	5.70	5.60	2.60	3.50	6.05	6.80	1.25	44.40
1878	5.25	2.20	3.70	3.39	4.53	2.62	5.47	2.50	6.05	3.00	2.10	3.60	44.41
1879	2.50	1.95	3.35	3.29	1.80	7.25	1.90	5.75	2.50	1.10	1.60	6.10	39.09
1880	4.45	3.85	2.00	3.00	1.70	5.20	4.85	1.15	1.87	1.90	3.55	1.25	34.77
1881	2.90	4.12	5.05	—	—	—	—	—	—	—	—	—	—
Average	2.88	2.79	3.52	2.26	2.47	3.67	3.89	4.21	3.52	3.44	3.45	2.82	38.92

Records of unusually heavy precipitation

Allentown

Inches		
4.88	....about 35 hours	Sept. 29-30, 1924
4.77	....24 hours ending 8 a. m.	Aug. 24, 1933
4.05	....about 25 hours	Sept. 7-8, 1934
5.67	....48 hours ending 8 a. m.	July 8-9, 1935

Bethlehem

4.10	....within 24 hours	Aug. 2-3, 1885
4.80	....within 24 hours	July 5-6, 1887
4.50	....within 24 hours	Aug. 21, 1888
4.70	....within 24 hours	Sept. 17, 1888
3.29	....40 minutes	Sept. 8, 1894
4.67	....within 24 hours	Feb. 6, 1896
3.08	....2 hours	May 28, 1896
3.63	....4½ hours	June 11, 1903
4.56	....20½ hours	June 11, 1903
4.45	....within 24 hours	June 12-13, 1903
3.27	....9 hours	July 30, 1918
9.07	....one storm (6 days)	July 16-21, 1919
4.08	....25 hours	Aug. 23-24, 1933
4.11	....25 hours	Nov. 29-30, 1934
5.10	....24 hours	July 9, 1935
9.96	....3 days	July 8-10, 1935
5.44	....about 42 hours	Oct. 30-31, 1935

Easton

5.21		Aug. 3, 1885
3.11		July 5-6, 1887
3.08		Jan. 1, 1888
3.34		Aug. 4, 1888
3.94		Aug. 21-22, 1888
3.90		Sept. 19-20, 1894
3.74	....about 18 hours	Feb. 6, 1896
3.95	....about 14 hours	Aug. 26-27, 1899
5.11		Sept. 25-26, 1902
3.30	....22 hours and 20 minutes	June 11-12, 1903
7.21	....about 12 hours	Oct. 9-10, 1903
4.15		Aug. 5-6, 1904

Coopersburg

7.12		May 20-21, 1894
3.88		May 28, 1894
3.47	....during the night	Feb. 5-6, 1896
3.58		May 12-13, 1897
3.50		Nov. 1-2, 1897
1.30	....30 minutes	Aug. 10, 1899
3.10	....during night	Aug. 26-27, 1899

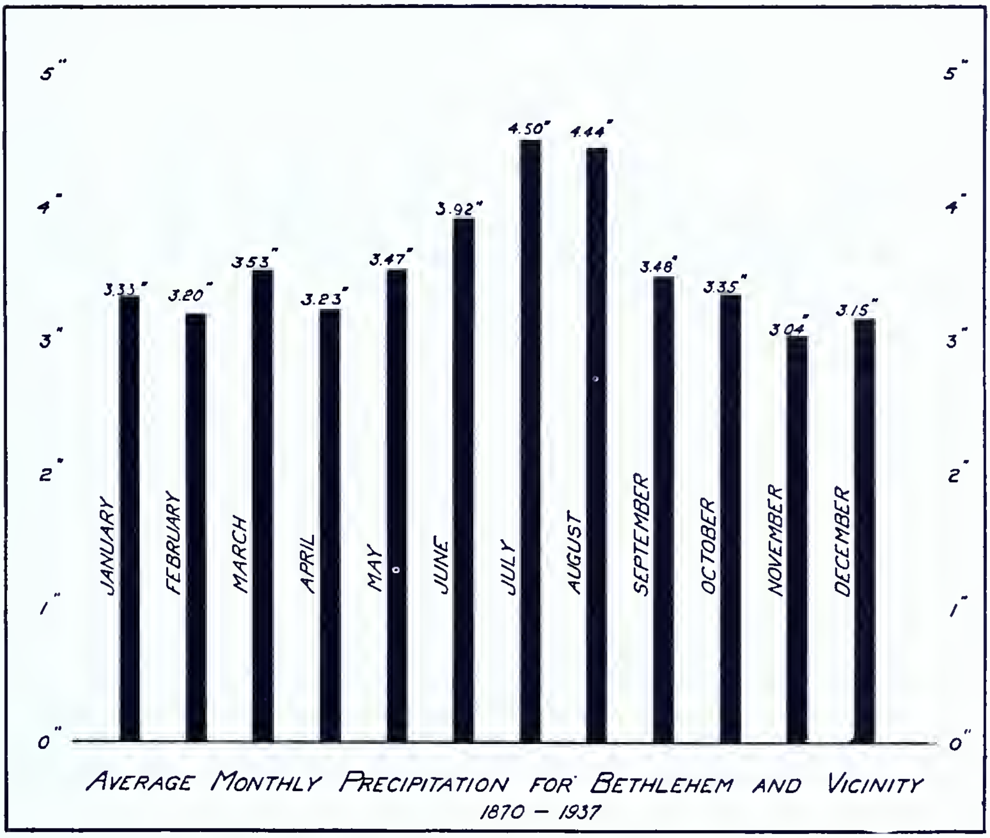


Figure 13.

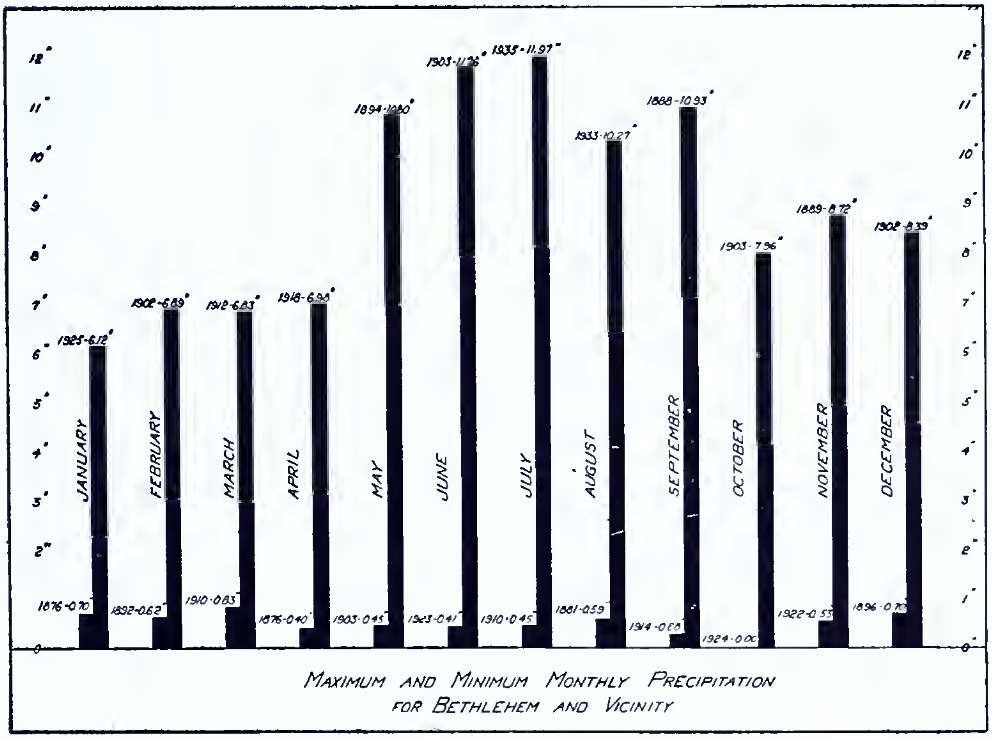


Figure 14.

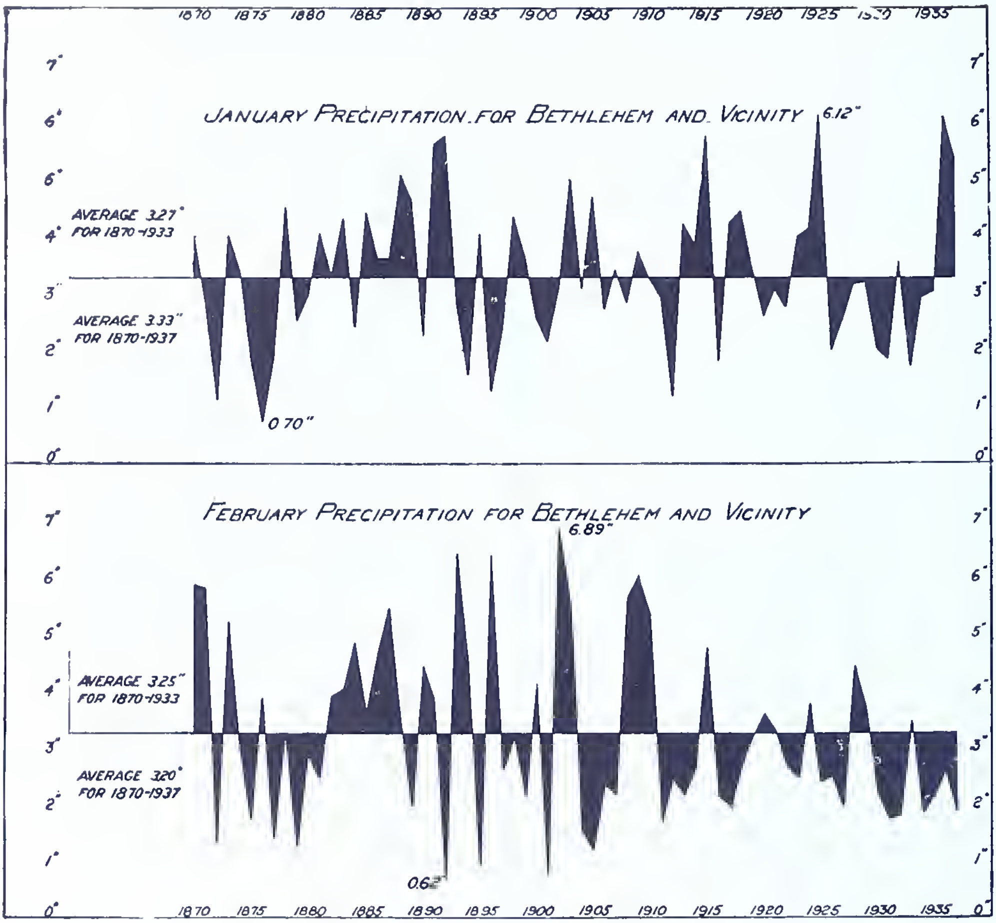


Figure 15.

The tables for precipitation include both rain and snow, as the common practice is to melt the snow and measure the resulting water. Reliable figures of precipitation extending over considerable periods are available for Allentown, Bethlehem, Coopersburg, Easton and North Whitehall and Egypt. These are presented in the following pages and show well the variations in precipitation that occur in the Lehigh Valley. Attention is directed to a few of these. The average annual precipitation is about 43 inches, but it has varied from 29.65 at Allentown in 1930 to 63.97 at Easton in 1889. The rainfall is fairly well distributed throughout the year. The average rainfall during July and August is in excess of four inches. June averages almost as high. The other months average somewhat more than three inches. The greatest monthly rainfall on record was 14.78 inches at Coopersburg in May 1894. In regard to minimum precipitation, it can be seen that with the exception of January every month in the year at some time or place has had less than one inch of rainfall. The lowest for January was 1.03 inches at Easton in 1896. October 1924 at Bethlehem had no measureable precipitation for the entire month.

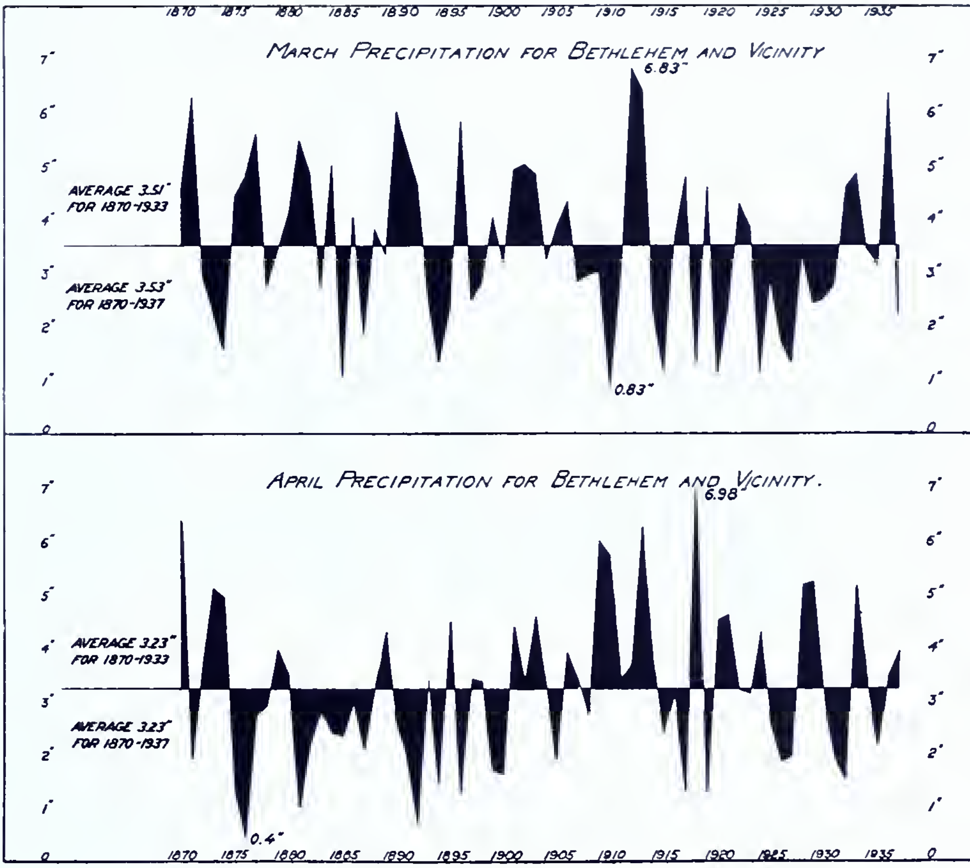


Figure 16.

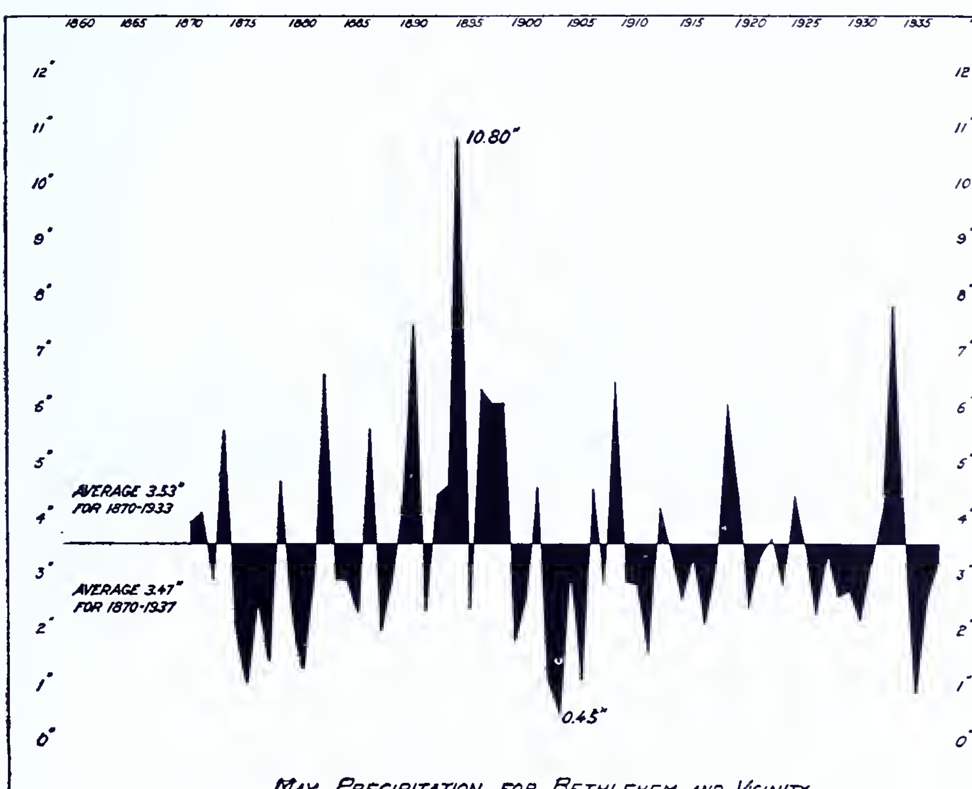


Figure 17.

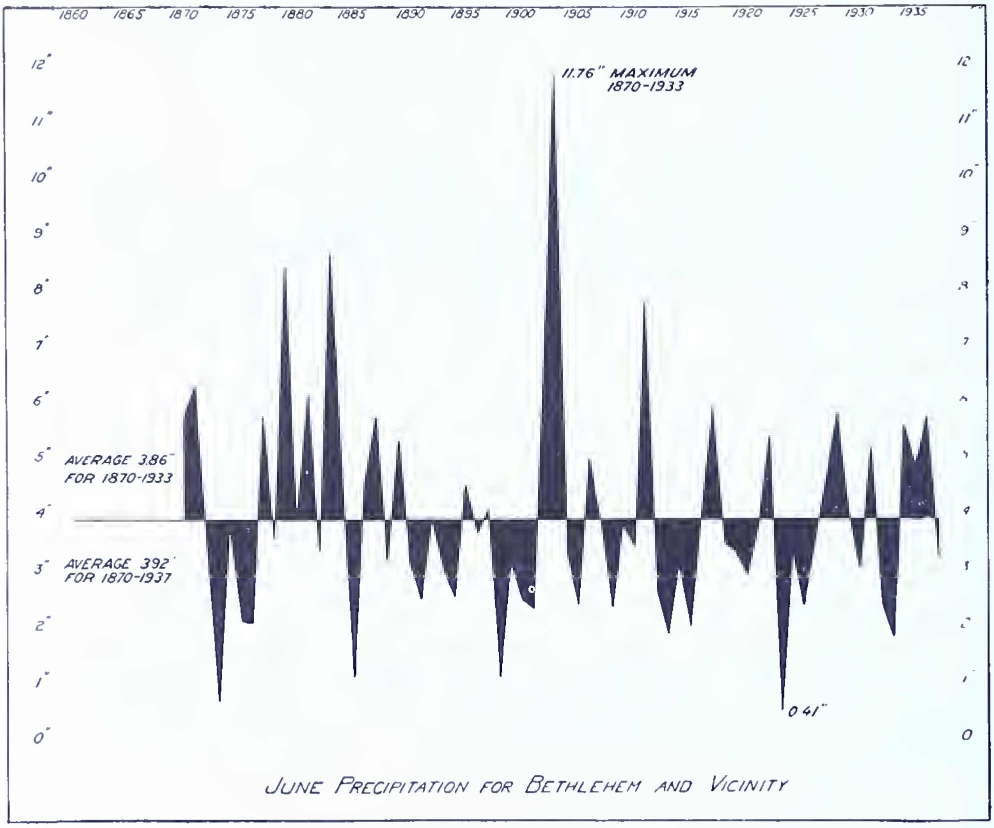


Figure 18.

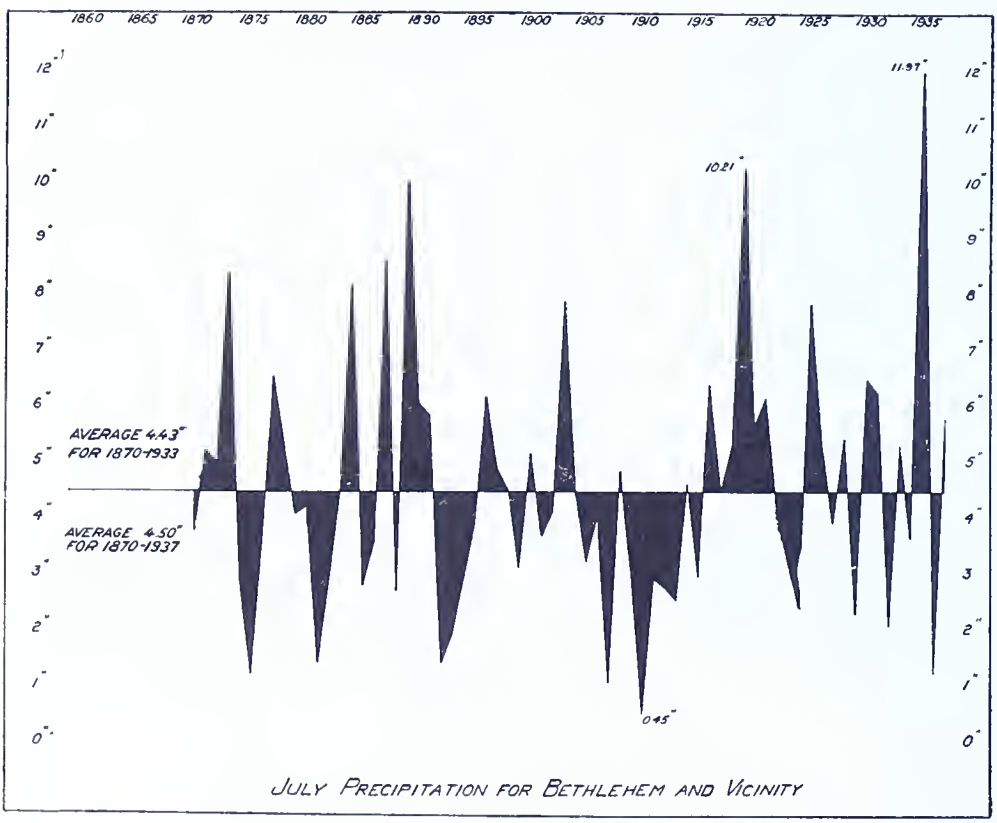


Figure 19.

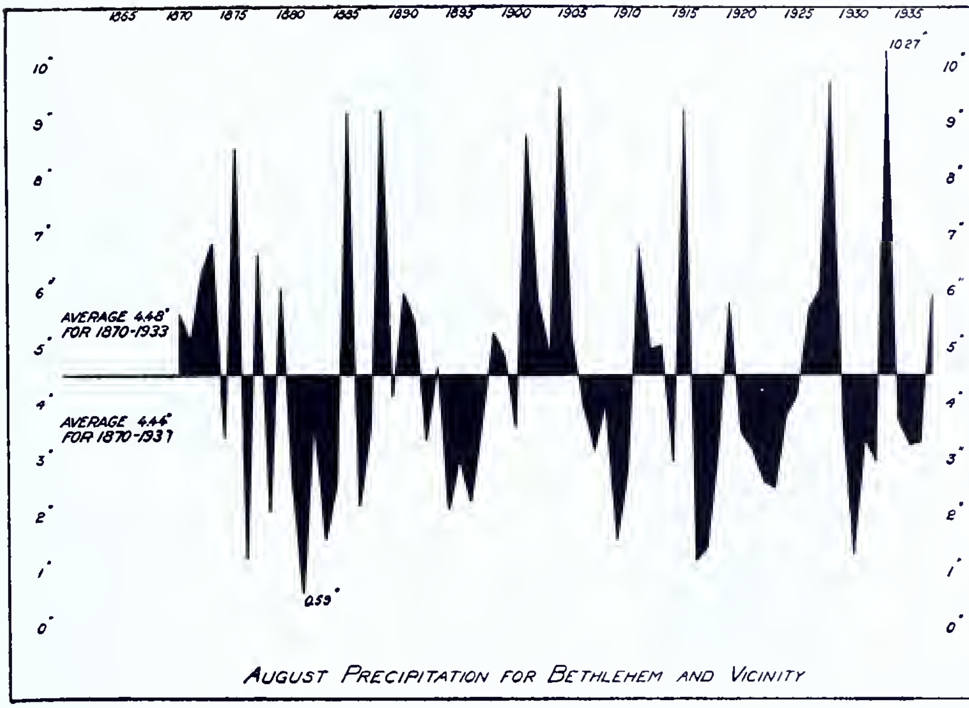


Figure 20.

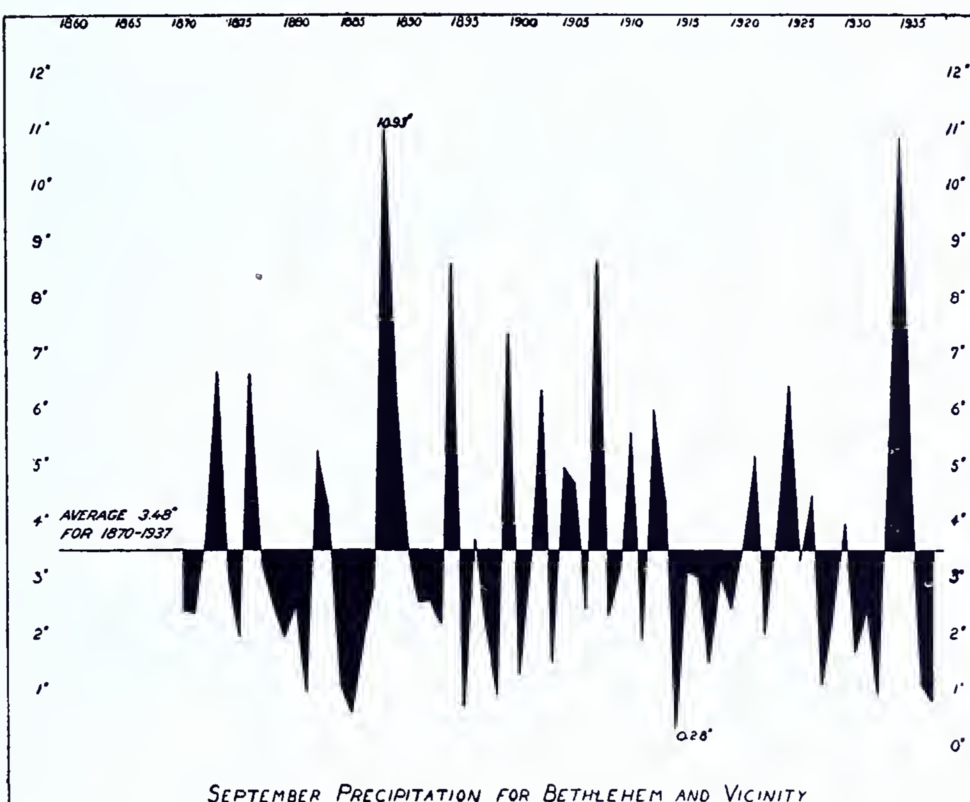


Figure 21.

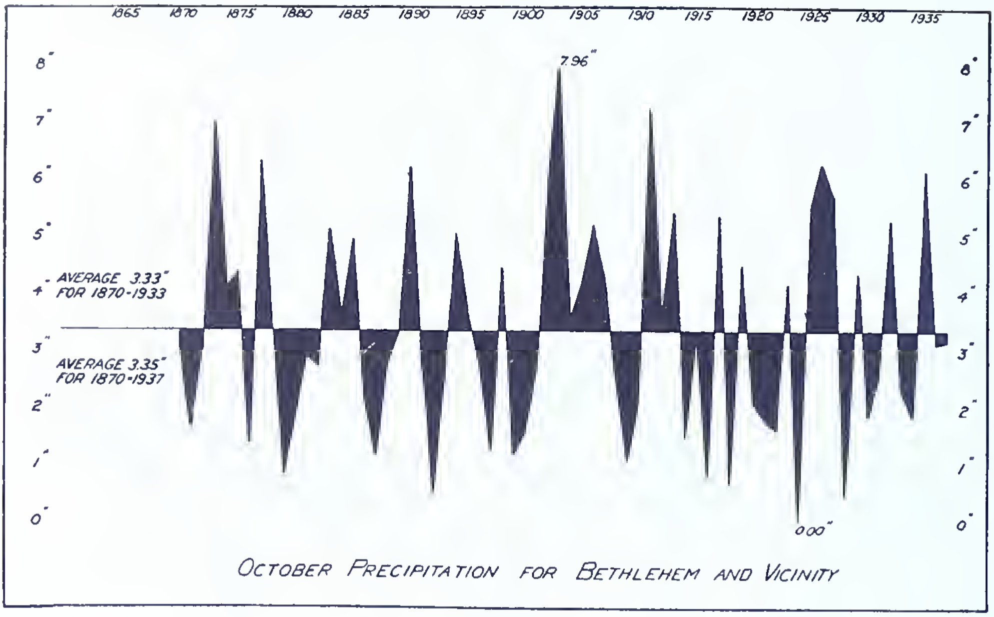


Figure 22.

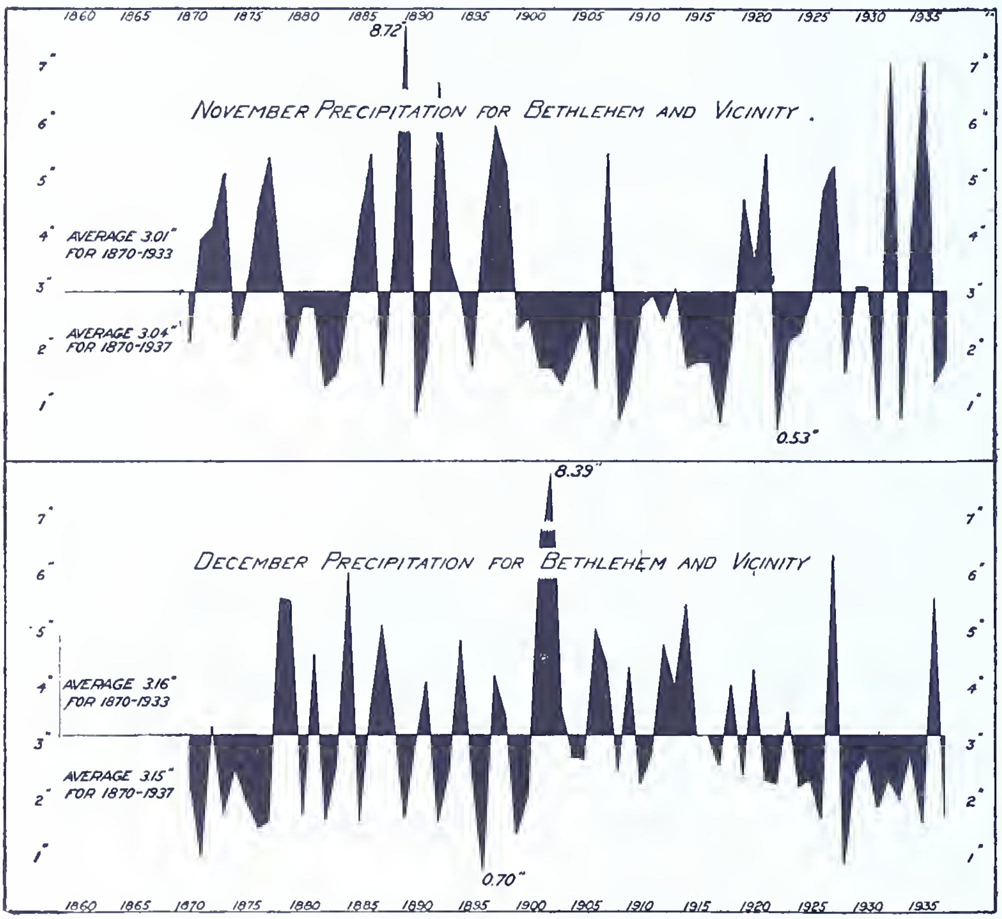


Figure 23.

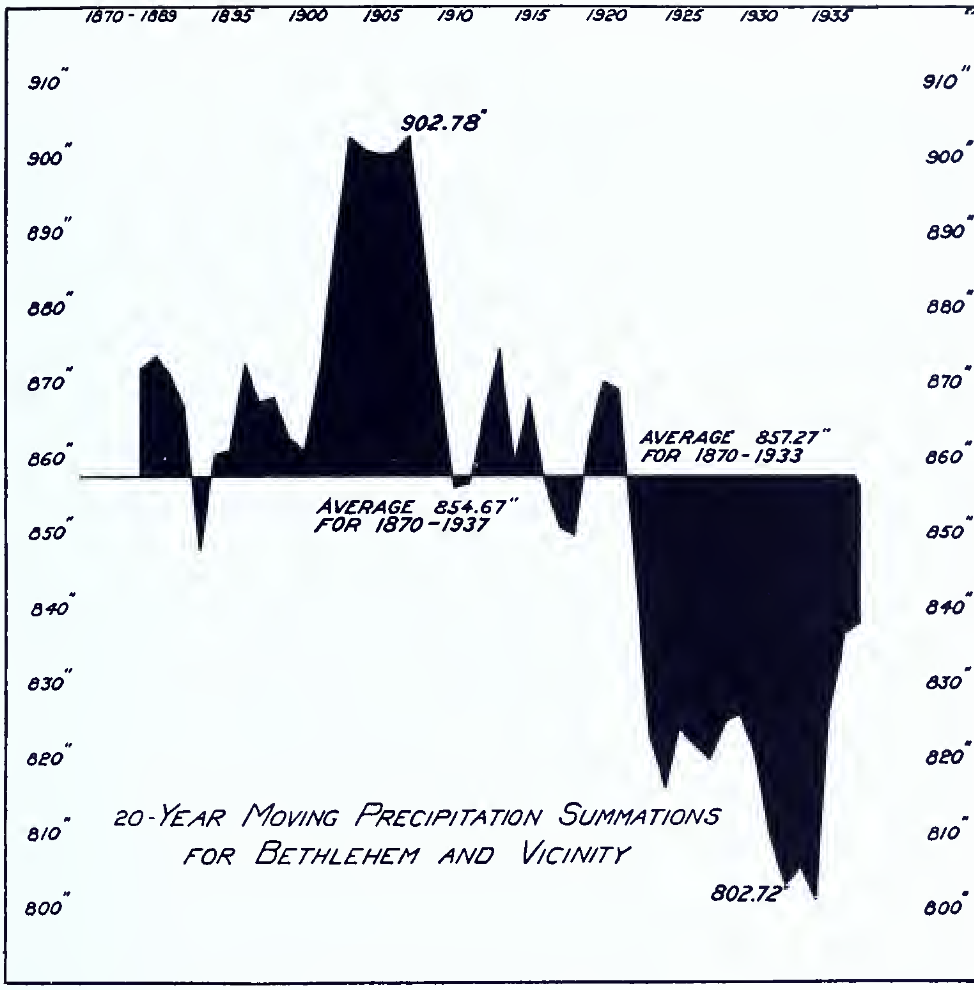


Figure 24.

See note on page 93

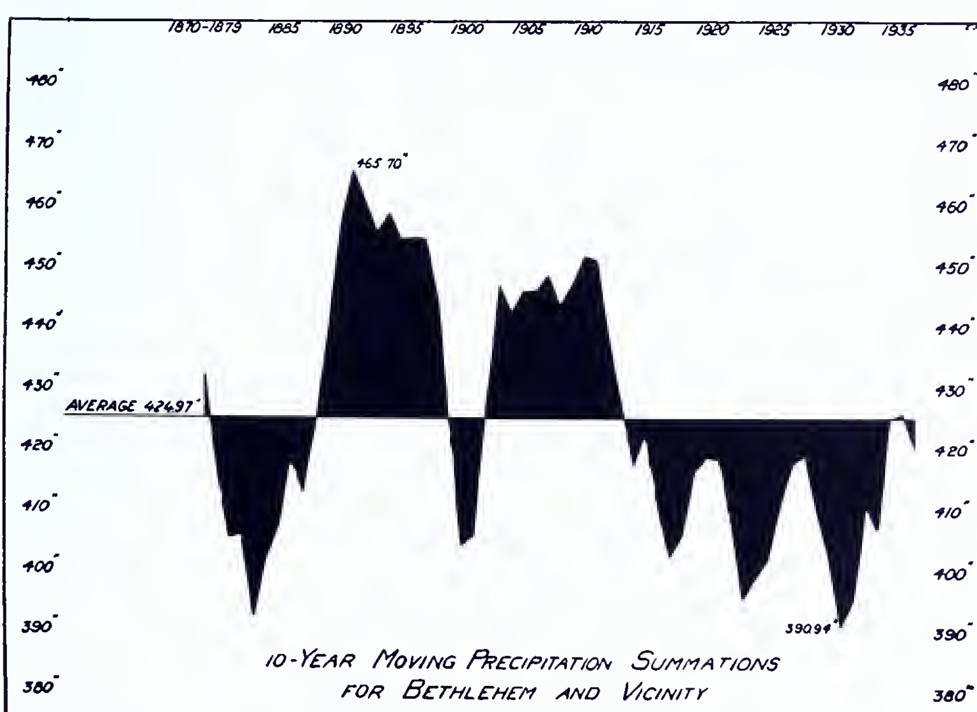


Figure 25.

Snowfall

The snowfall records have been included in the precipitation data, but it is well to discuss the snowfalls of the region separately. The data on snow are less abundant and less accurate than on other topics. There is enough, however, to warrant one in saying positively that there has been no marked change, in spite of the equally positive statements of many of the older inhabitants to the effect that in their youth there was much more snow than in recent years. Certainly snows of the period before hard roads, automobiles, and State supervision resulted in more inconvenience and also were utilized for sleighing to a far greater degree than at present when sleighs have practically disappeared. The greatest importance of snow is the protection which it affords the winter wheat and other plants.

There is great variation in the snowfall both as to amount and to time of occurrence. The months of greatest fall are December, January and February, although occasional heavy falls occur during November and March. In most sections the heaviest single snow on record occurred on March 10-12, 1888, when a depth between twenty and thirty inches was measured in some places. Even during April and October snow occasionally covers the ground for a short time and snow flurries occur during May and September. A very late snow in the spring is commonly termed the "onion snow."

Figures of annual snowfall measured at Allentown for twelve years, Bethlehem for twenty years and Easton for seven years give an average annual snowfall of 23.84 inches for Allentown, 27.50 inches for Bethlehem and 27.07 inches for Easton. This is evidently too low as a general average as it includes several years of abnormally light snows. A fairer average would be near 30 inches. Philadelphia over a period of 58 years has an average of 24.3 inches. The average seasonal snowfall for Reading is 29.5 inches. As it is a common occurrence in winter to have a storm passing through eastern Pennsylvania yield rain in Philadelphia and snow in the Lehigh Valley the snowfall for this region over a longer term of years should be considerably higher than Philadelphia and slightly higher than Reading.

Snowfall (unmelted) in the Lehigh Valley
(In inches, tenths and hundreths)

Place	Year	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.	Annual
Easton	1906	3.3	6.6	12.8	0	4.5	3.0	30.2
Easton	1907	11.5	8.5	10.5	1.8	1.8	6.8	40.9
Easton	1908	4.0	13.5	4.8	0	5.8	4.6	32.7
Easton	1909	9.0	2.2	8.7	0.2	—*	—	
Bethlehem	1910	—	8.0	0.7	0	—	12.2	
Bethlehem	1911	2.5	10.8	8.0	2.5	5.8	1.5	31.1
Bethlehem	1912	7.4	3.0	0	0	0	13.5	23.9
Bethlehem	1913	0.5	2.6	0	0	0	3.0	6.1
Bethlehem	1914	0.2	21.5	12.5	0	0	6.0	40.2
Bethlehem	1915	—	Tr.	8.1	5.0	—	—	
Bethlehem	1916	—	8.5	16.5	7.0	0	0.9	
Bethlehem	1917	6.0	14.0	20.5	0	0	18.0	58.5
Bethlehem	1918	24.3	2.0	0	9.0	0	0	35.3
Bethlehem	1919	—	1.0	0	0	0	10.5	
Bethlehem	1920	11.5	23.0	0	0	1.5	—	
Bethlehem	1921	3.0	21.0	0	0	0	5.5	29.5
Bethlehem	1922	25.0	9.5	—	—	—	—	
Allentown	1923	12.0	—	—	0	Tr.	2.5	
Bethlehem	1923	17.0	13.5	7.0	0	0	2.0	39.5
Allentown	1924	—	12.2	—	12.0	Tr.	0.2	
Bethlehem	1924	—	14.5	—	15.0	Tr.	—	
Allentown	1925	43.2	—	Tr.	0	1.7	0.7	†
Bethlehem	1925	—	—	Tr.	0	1.5	3.8	
Allentown	1926	3.9	25.0	0.4	Tr.	Tr.	6.6	35.9
Bethlehem	1926	2.4	17.4	Tr.	Tr.	Tr.	6.8	26.6
Allentown	1927	5.1	10.1	0	0	Tr.	2.0	17.2
Bethlehem	1927	5.4	10.1	Tr.	0	Tr.	5.0	20.5
Easton	1927	—	—	—	—	0.5	3.0	
Allentown	1928	12.0	4.6	11.0	Tr.	Tr.	0.3	27.9
Bethlehem	1928	11.0	7.0	12.8	0	Tr.	0.7	31.5
Easton	1928	13.0	5.5	8.2	0.3	Tr.	3.0	29.73
Allentown	1929	2.2	8.2	3.2	Tr.	Tr.	8.5	22.1
Bethlehem	1929	1.0	12.5	3.2	0	0.8	8.8	26.3
Easton	1929	6.5	11.3	1.5	0	3.0	9.0	31.3
Allentown	1930	9.8	3.0	0.5	0	Tr.	3.5	16.8
Bethlehem	1930	11.0	2.7	0.2	Tr.	Tr.	5.0	18.9
Easton	1930	8.5	2.3	0.5	0	—	7.4	
Allentown	1931	1.5	3.6	2.4	0	1.5	Tr.	9.0
Bethlehem	1931	1.8	3.3	2.5	0	3.2	2.5	13.3
Easton	1931	1.1	4.0	2.1	0	2.8	0.8	10.8
Allentown	1932	Tr.	1.3	2.2	Tr.	Tr.	9.4	12.9
Bethlehem	1932	Tr.	2.7	2.2	Tr.	Tr.	9.6	14.5
Easton	1932	Tr.	2.2	1.8	Tr.	Tr.	9.85	13.85
Allentown	1933	1.4	9.6	2.0	Tr.	2.2	9.9	25.1
Bethlehem	1933	1.8	9.4	Tr.	Tr.	6.9	8.4	26.5
Allentown	1934	Tr.	17.6	7.3	Tr.	Tr.	0.2	25.1
Bethlehem	1934	Tr.	18.0	5.3	Tr.	Tr.	1.1	24.4
Allentown	1935	10.8	9.4	3.0	0.2	1.6	8.2	33.2
Bethlehem	1935	12.5	8.2	0.5	Tr.	2.0	7.5	30.7
Allentown	1936	15.4	18.8	2.0	Tr.	1.5	3.0	40.7
Bethlehem	1936	14.2	14.3	2.4	Tr.	2.5	1.7	35.1
Allentown	1937	4.1	3.8	10.7	Tr.	0.1	1.5	20.2
Bethlehem	1937	3.0	3.2	10.6	Tr.	Tr.	0.8	17.6
Average								
Allentown		8.68	9.78	3.44		.57	3.77	23.84‡
Bethlehem		7.34	9.69	4.34		.97	5.62	27.50
Easton		6.32	6.23	5.66		2.30	5.27	27.07

* No record.
† In October 1925, 2.2 inches at Allentown and 3.0 inches at Bethlehem.
‡ Average of complete annual records.

Humidity

In recent years considerable attention has been given to the relative humidity of the atmosphere. High humidity in hot weather produces an oppressive feeling and results in numerous sunstrokes or heat strokes because of slow evaporation of the body perspiration. In cold weather high humidity increases the rate of conduction of heat from the body and produces chilliness. The east wind of an approaching storm always feels much colder in the winter because of the increase in the relative humidity.

Continuous relative humidity charts from a recording hair hygrometer for the past thirteen years are on file in Lehigh University. These show great variations ranging from 15 to 100 percent. Except when precipitation is actually taking place, the relative humidity seldom rises higher than 85 percent. It also rarely measures less than 15 percent. In addition to the recording instrument data, each day at 4:00 P. M. Eastern Standard Time, the relative humidity is obtained by means of a whirled psychrometer. The averages of relative humidity for each month determined in this way, of the years 1928 to 1937 inclusive are given in the following table.

Relative humidity monthly averages determined at Lehigh University daily at 4:00 P. M. (Eastern Standard Time) from 1928 to 1937, inclusive.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1928	—	—	—	47.0	42.3	58.3	56.2	62.4	54.2	53.9	61.4	58.3	55.2
1929	59.6	58.3	50.1	54.3	48.6	43.9	43.7	46.8	56.6	53.7	60.3	65.0	53.7
1930	65.1	68.4	50.3	46.8	45.3	46.6	49.8	42.7	44.9	43.2	57.4	62.8	52.4
1931	55.0	53.4	56.0	43.0	49.1	45.3	48.7	53.2	55.1	49.9	58.5	55.2	51.8
1932	63.0	51.7	51.3	38.6	40.0	50.4	39.1	40.5	37.2	51.5	54.7	63.6	48.4
1933	57.9	53.3	59.2	52.3	61.7	51.6	54.4	60.3	57.6	51.4	59.7	63.2	56.8
1934	61.1	50.4	55.2	49.8	52.3	55.2	53.7	56.7	67.7	49.2	58.4	54.7	55.5
1935	62.3	55.5	52.5	48.5	39.5	49.8	54.2	51.3	52.8	48.1	69.8	65.4	54.1
1936	67.8	60.0	63.0	54.3	44.0	51.2	40.9	46.4	53.7	51.4	50.9	58.6	53.6
1937	64.4	47.3	48.3	47.2	49.8	62.7	54.8	63.8	57.8	48.5	47.6	49.4	53.5
Average	61.8	55.4	54.0	48.2	47.3	51.5	49.6	52.4	54.8	50.1	57.9	59.6	53.5

General Character of Weather

The meteorological observers in the Lehigh Valley have usually recorded the general character of each day as clear, cloudy, or partly cloudy and have also noted the days in which .01 inch of precipitation has occurred. At Lehigh University since December 1925 there has been in operation a sunshine recorder such as is used at the principal stations of the U. S. Weather Bureau and since that time the record for sunshine is almost complete. These record sheets are preserved at the university.

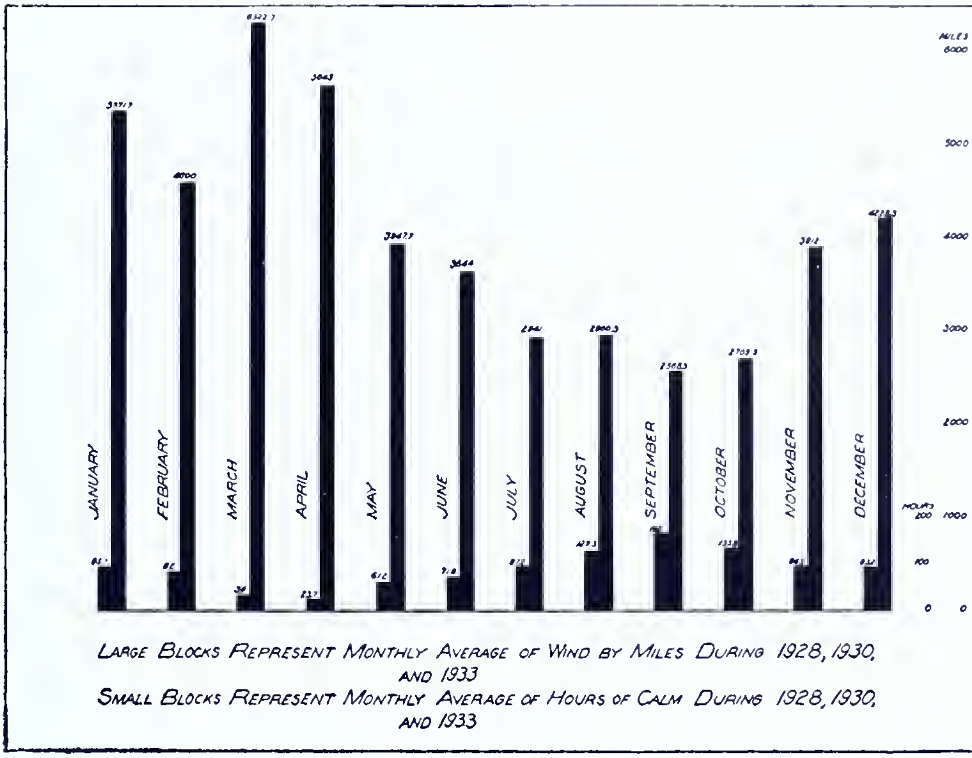


Figure 26.

Winds

The winds of the Lehigh Valley are generally light. They blow most of the time from the west, southwest or northwest, inasmuch as the region is in the Prevailing Westerlies wind belt. The storms also almost invariably come from the same directions and pass in an easterly direction. During the summer months the prevailing direction is usually from the southwest and during the winter from the northwest. The wind changes direction with the passing of a storm, as is discussed below. The usual wind velocity is about five to seven miles an hour except during storms.

The greatest wind velocity recorded at Bethlehem since the establishment of the automatic recording instruments in 1925 was 45 miles per hour on December 20, 1934. Because this instrument makes a record only on the completion of each mile of wind blown, it is certain that occasional gusts have much higher velocity. It is estimated that the maximum is perhaps 60 miles per hour.

Since December 1925 continuous automatic records of wind direction and velocity have been obtained at the Lehigh University meteorological station and are preserved there.

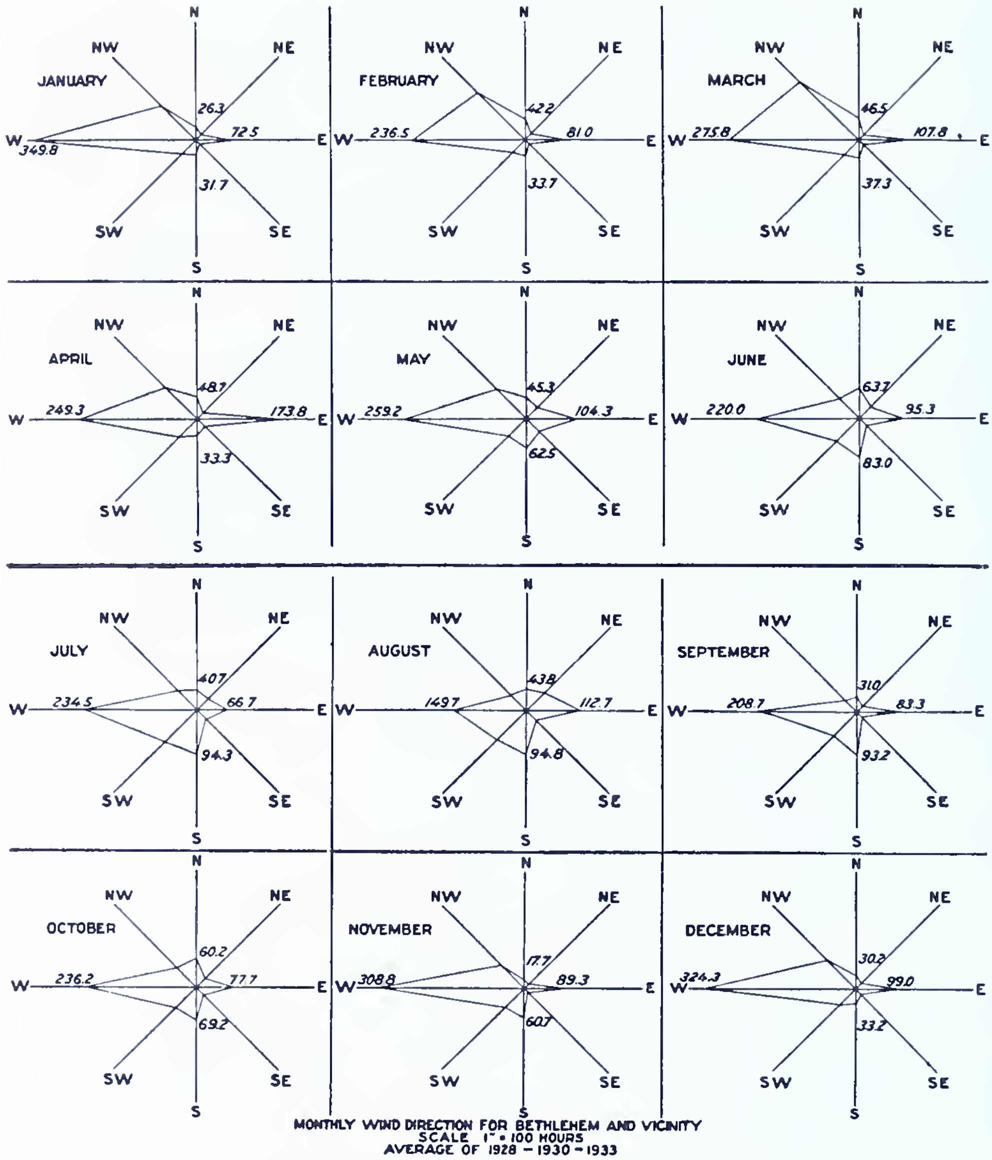


Figure 27. Monthly wind direction for Bethlehem and vicinity.

Storms

Two kinds of storms bring practically all the precipitation in the Lehigh Valley and effect the greatest changes in temperature and in the winds. These are the extratropical cyclones and the thunderstorms. In some respects these are not definitely separable as the thunderstorms may be a part of the larger cyclones.

Extratropical Cyclones

The extratropical cyclones are great spirally whirling masses of air several hundred miles in diameter that sweep across the country from

west to east during most of the year, but especially noticeable during the winter. On the daily weather map they appear as areas of low pressure and are generally called "lows."

The approach of one of the storms is marked by a gradual but decided drop in the barometric pressure, the winds shifting to the southeast, east, or northeast, increasing humidity, increasing cloudiness, and generally a slight increase in temperature. So regular are these changes that one can make fairly accurate predictions of an approaching storm from twelve to twenty-four hours in advance of the beginning of precipitation. The wind may blow from the east for a day or more before rain or snow starts to fall. Precipitation, having started, continues more or less steadily as long as the wind remains in the east and the barometer is falling. Sometimes in late fall, winter or spring the storm may last two to three days, or rarely even longer, and the rain from a single storm amount to several inches. During the summer these storms are much less pronounced and one that appears fairly well developed in the central part of the country may disappear before reaching the Atlantic border. The winds in these storms are not often strong enough to do much damage in Pennsylvania although along the ocean these east or northeast winds result in considerable shore erosion and damage to coastwise shipping. The strength of the winds is determined mainly by the rapidity with which the barometer falls.

The ending of one of these storms is marked by the rise in the barometer; the cessation of precipitation and gradually clearing skies; decided drop in temperature producing, when extreme, what are known as "cold waves;" and the shifting of the winds to the northwest or west and marked increase in their velocity.

In normal winter weather a storm of this kind passes through eastern Pennsylvania about every four or five days, but there is much variation. In the summer the "lows" normally move more slowly and are less pronounced. Occasionally such a storm passes with all the usual pressure and temperature changes but without precipitation.

Thunderstorms

Thunderstorms are a characteristic feature of the summer months in the Lehigh Valley, although they have occurred in every month of the year. During the growing season, and especially in July and August, practically all the precipitation may be received from storms of this kind; the extratropical cyclones may be scarcely noticeable. Thunderstorms also commonly accompany the extratropical cyclones and are most frequent when the southeast quadrant of the larger storm passes through a region. Although many thunderstorms are

extremely local, with a path only a few miles wide, other single ones may extend over a large part of the State. The rainfall from a single storm may be excessive and cause disastrous local floods. The winds also reach occasionally velocities of forty to fifty miles per hour and much damage is done to trees and property. The annual property loss due to lightning is also no small factor and a few deaths each summer from this cause are not unusual. Notwithstanding their destructiveness, thunderstorms are the salvation of the crops in the Lehigh Valley each summer.

The frequency of thunderstorms is extremely variable. During periods of high temperature they may be an almost daily occurrence, although not often in exactly the same place day after day. At other times they may be quite rare. They most commonly break in the late afternoon or early evening but do occur at almost every hour of the day. After the thunder, lightning and wind have subsided the skies may clear in just a few minutes, but occasionally gentle rain may continue for many hours.

The passage of a severe thunderstorm almost invariably results in a decided drop in temperature. Within a few hours the temperature may fall as much as thirty to forty degrees, passing from excessively hot to abnormally cool. Prolonged excessively hot periods are apt to end with heavy thunderstorms followed by decidedly chilly weather.

Other Storms

The Lehigh Valley is visited occasionally by other types of storms, such as the West Indian hurricanes and tornadoes. The former, originating in the West Indies where they are so destructive, sometimes sweep up the Atlantic Coast and bring heavy rain and high winds. By the time they reach Pennsylvania they have lost much of their force and are similar in almost every respect to the extratropical cyclones previously described. When they do pass over eastern Pennsylvania they bring extremely heavy rain and unusually low barometeric pressures. In the West Indian storm of August 22-24, 1933, which passed over the region, the rainfall amounted to 5.76 inches. The resulting flood did much damage. These hurricanes move very slowly in Pennsylvania so that rain may fall almost continuously for three or four days.

Tornadoes with their whirling funnel-like clouds are rare in this section, but have occurred. They are merely thunderstorms concentrated to a diameter of only a few hundred feet. Within that area the twisting winds attain hurricane velocity sufficient to raze almost any structure in their path.

PHYSIOGRAPHY

By Benjamin L. Miller

The most casual observer crossing Northampton County from north to south notes differences in the topographic features, whereas a person traversing the county in a west-east direction notes few changes. It is the function of the geologist (geomorphologist) to differentiate, classify, name and explain these resemblances and differences. Numerous investigators have studied these forms in Northampton County or in other parts of the Appalachians. Because of the wide extent of each physiographic type represented in the region, studies made in somewhat distant sections are pertinent to this discussion.

There is general agreement regarding the main features but not in the minor divisions and in the nomenclature. The classification of Fenneman,[1] adopted by the U. S. Geological Survey, is mainly followed in this report.

According to this usage, Northampton County constitutes a small portion of the Appalachian Highlands which extends from Canada to central Alabama and from the Coastal Plain on the east to the Interior Plains on the west. This is divided into provinces and these in turn into sections. Northampton County contains portions of the following divisions.

[1]Fenneman, N. M., Annals Assoc. of Amer. Geographers, vol. 18, pp. 262-353, 1928.

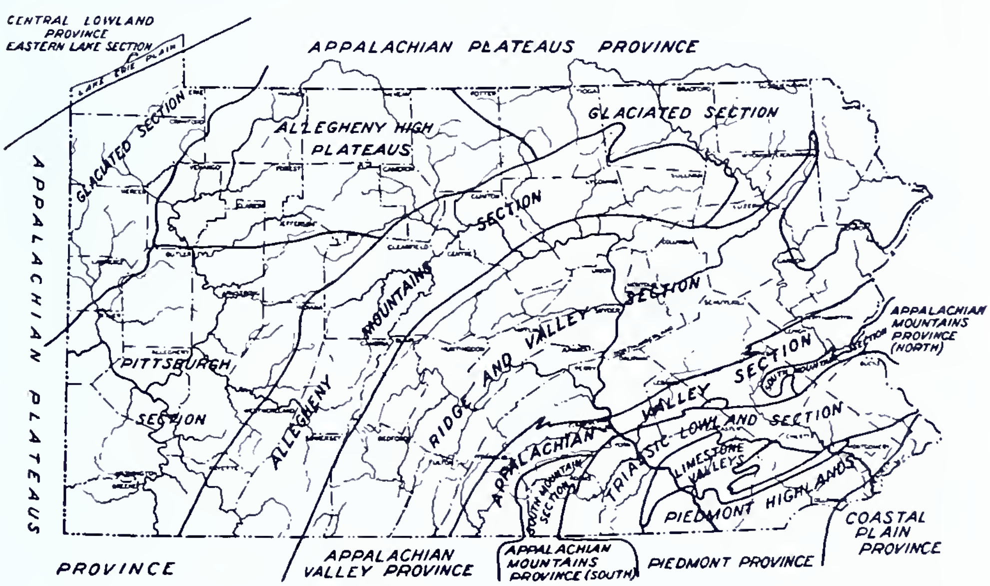


Figure 28. Physiographic subdivisions of Pennsylvania.

Physiographic divisions represented in Northampton County

Major division	*Province*	*Section*	*Distribution*
Appalachian Highlands	Piedmont Lowlands	Triassic Lowlands	Poorly represented in non-characteristic form in the extreme south corner of the county.
	New England Uplands (Also called *Older Appalachians*).	Reading Prong (Also called *Appalachian Mountains*).	Steep hills or ridges of crystalline rocks, irregular in form, separated by flat-bottomed valleys of limestone. Geographically these are South Mountains or the Durham and Reading Hills. This includes practically all the area lying south of the Lehigh River.
	Ridge and Valley Province* (Also called *Newer Appalachians* and *Folded Appalachians*).	Portion between South Mountains (Durham and Reading Hills) and Kittatinny (Blue) Mountain is called *Appalachian Valley* and *Lehigh Valley.*	Areas of limestones and slates.
		Kittatinny (Blue) Mountain.	Ridge of Silurian (Shawangunk) sandstones and conglomerates.

Topographic Characteristics

It is doubtful whether another area of like size within the entire United States has received as much attention from physiographers and geologists as Northampton County. The extensive bibliography presented in another chapter is largely the numerous articles that have been written on the Delaware Water Gap, Wind Gap, Lehigh Gap and the peneplanes of Northampton County. These features have been taken as types of such forms and described in scores of articles and textbooks. At an early date explorers and travelers noted these striking topographic forms and offered strange explanations as to their origin. In recent years trained investigators have studied them in detail and have disagreed in so many points that the writer enters this field of controversy with extreme reluctance. He therefore presents descriptions of the phenomena and the theories of different investigators. Although preference for particular views may be shown, an attempt is made to leave the acceptance or rejection of various ideas to the individual reader and to future students.

* Some writers have limited the Ridge and Valley division to that portion of the Appalachian Highlands lying between the Allegheny Mountains (or Plateau) and the Appalachian Valley. According to this usage, Kittatinny (Blue) Mountain is the only part of the Ridge and Valley province present in Northampton County.

When that stimulating and earnest student of land forms, William Morris Davis, wrote his articles on the streams of Pennsylvania and New Jersey in volumes I and II of the National Geographic Magazine he initiated the scientific investigation of the topographic features of this region. Before Davis wrote, there were occasional notes by other geologists. In 1883 J. P. Lesley[2] called attention to three prominent plains (planes) in the region. Of Kittatinny (Blue) Mountain he said, "Its crest a nearly horizontal line everywhere about the same height (1,500 to 1,600 feet above the sea)." (p. 23.)

He described the topography of the slate region as follows: "The slate belt of Northampton County stretches from the Delaware to the Lehigh for seven miles south of the mountain. It is (a) region of low flat-topped hills, trenched by a multitude of small valleys, and when looked down upon from the mountain, appears like a great plain, which it really is." (p. 27.) He describes the limestone region in the following sentences. "*The limestone plain* of Northampton County is about seven miles wide, and elevated * * * about 400 feet above tide; its hill tops sometimes reach 450 feet. This plain is intersected in every direction by gently sloping vales." (p. 36.)

A mere casual examination of the topographic map reveals four sharply distinct topographic regions. From north to south these are Kittatinny Mountain, the slate region, the limestone valley and the hills south of the Lehigh River. These will be described in turn. The first three belong to the Ridge and Valley Physiographic Province and the last one to the Reading Prong of the New England Uplands.

In some regions the topographic features have little relation to the stratigraphy. In Northampton County, however, each of the erosion surfaces (peneplanes?) is almost completely confined to a particular formation or group of formations. This has resulted in a discussion as to whether the successive more or less level surfaces should be designated as peneplanes or not. At this point they will be described as topographic features only and called erosion surfaces. Their origin will be discussed on later pages.

Kittatinny (Blue) Mountain.—This even-crested mountain ridge, visible on a clear day for long distances, is the most regular and most impressive topographic feature of the entire region. Viewed from the distance, it has the appearance of the edge or the escarpment of an elevated plateau. When one climbs it and finds that the mountain is a narrow ridge with the top scarcely wider than one-fourth mile any place and generally much narrower, the mountain then appears as a barrier ridge. The hard Shawangunk conglomerates and

[2] Sec. Geol. Survey of Pa., D 3, vol. 1, 1883.

sandstones forming the mountain dip to the northwest at angles varying from 30° to 60°. The Martinsburg shales beneath dip in the same direction, likewise at various angles. The contact between the two formations, seldom observable on account of the hillside talus, is generally about half way up the southern slope.

The crowding of the contours shown on the map indicates the steepness of the slopes. They can be climbed by the pedestrian only with considerable difficulty. The five roads that cross the mountain between the Delaware Water Gap and the Lehigh Gap all do so by diagonal or zigzag courses and finally cross the crest in notches or minor gaps. No tributary stream crosses the ridge between the Delaware and Lehigh rivers although each of these major streams receives numerous tributaries from either side both to the north and the south of the mountain. With the exception of two flexures in the rocks of the mountain known as the Big Offset and the Little Offset, the mountain is a single ridge with a remarkably straight trend to the west-southwest. Although the general appearance of the mountain on the skyline is that of a straight line, closer inspection and the examination of the map shows considerable variation in elevations. Ignoring the gaps or notches, the crest varies from 1,400 to 1,665 feet above sea level. Some persons have been inclined to suggest two levels of different altitude but since there is no marked separation between the two, it seems preferable to regard these varying elevations as due either to crustal warping or to varying amounts of erosional degradation.

Kittatinny Mountain may be said to typify what is regarded as a peneplane remnant, the remaining portion of an extensive plane of erosion that at one time extended throughout the entire Appalachian region. It was once believed that during Cretaceous time the tops of the folded Appalachians were worn down to base level. More recently the date for this leveling has been placed in middle or late Tertiary time. Subsequent elevation has permitted the removal of the softer, less resistant rocks on both sides, as discussed more fully on a later page. Other similar ridges lie to the northwest of Kittatinny Mountain in adjoining counties. In some places there are several parallel ridges separated by steep-sided valleys. In every case the ridges are composed of hard resistant rocks and the valleys cut in shales or in a few places in limestones. Along the Susquehanna River the continuation of Kittatinny Mountain is called First Mountain and is followed northwestward by Second and Third mountains.

Slate (Shale) Region.—The concordant tops of the stream divides in the slate belt are noted by the traveler. If the narrow stream valleys could be filled, the region would appear as an unusually well-

developed plane interrupted here and there by low hills of sandstone approximately parallel in direction to the trend of Kittatinny Mountain. Most of the stream divides, composed of slate, are from 600 to 800 feet above sea level, whereas those hills of sandstone attain a height of over 900 feet. One hill east of Point Phillip rises to 989 feet. The slate region extends across the northern portion of the county in a belt from six to nine miles in width, interrupted only by the limestone area in the vicinity of Portland.

The streams of the slate region are numerous and have dissected the region, producing scores of steep-sided valleys.

The hillsides of the region are characteristic. The slopes are symmetrically rounded near the tops of the divides and sides are steep in proximity to the streams. Anyone familiar with this type of topography could scarcely fail to identify it as characteristic of a slate region and distinctly unlike anything to be seen in other portions of the county.

Limestone Valley.—That part of the county occupied by the Cambrian and Ordovician limestones possesses a distinctly different appearance. The interstream areas are broad and so nearly flat that in many places one can not note any irregularities of more than a few feet for distances of several miles. The streams are few and, with the exception of the Lehigh and Delaware rivers, commonly have very gentle valley slopes. The average elevation of the divides is about 400 feet . A few hills rise 20 to 60 feet above, and some sinks are 20 or more feet below the general level. The Lehigh and Delaware rivers and the lower courses of their tributaries are about 200 feet below the general level of the uplands.

The relatively few surface streams as compared with the slate region, and the numerous sinks bear witness to the development of an extensive underground drainage system.

Camels Hump and Pine Top a few miles north of Bethlehem, and Chestnut Hill north of Easton are hills of resistant pre-Cambrian rocks that have been brought to the surface by profound faulting, and rise conspicuously above the general limestone plane.

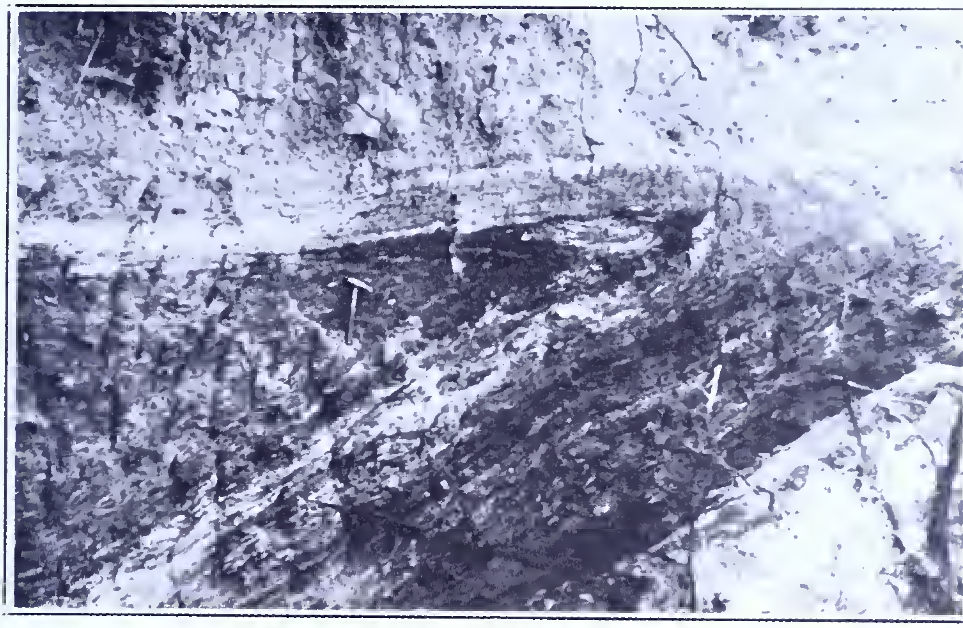
South Mountains.—The hills south of the Lehigh River present a striking contrast to the topographic features previously described. They are part of the Reading Prong of the New England Uplands and are composed mostly of pre-Cambrian crystalline rocks of various kinds but with intervening, partly enclosed valleys floored with Paleozoic sediments, especially limestones. This belt is continuous with the New England Physiographic Province which comprises practically all of the New England States. The narrow prong six to eight miles wide extends to the Schuylkill River in the vicinity of Reading where

PLATE 3.

A. Hexenkopf Rock (Pochuck gneiss), top of Hexenkopf Hill.

B. Tree enlarging joint in Pochuck gneiss, Hexenkopf Hill.

PLATE 4.



A. Hill side creep simulating a fold in decomposed shaly Hardyston. Half a mile east of Hellertown.

B. "Devil's Potato Patch," Little Gap. Shawangunk conglomeratic sandstone disintegrated by frost action.

the Triassic rocks come in contact with the Paleozoic limestones through an overlap. Beyond the Susquehanna River, the crystalline rocks again come to the surface and continue southwestward and southward to Georgia as the Blue Ridge Province.

Several different names have been applied to this belt of hills. The Second Geological Survey of Pennsylvania used the name Durham and Reading Hills. The mountain paralleling the Lehigh River between Bethlehem and Allentown has been called South Mountain and also Lehigh Mountain. Both of these names have also been applied to other portions of the belt. Names have been given to individual mountains also, as shown on the map.

The use of the term South Mountains in this region sometimes results in confusion as it has been used more commonly for the mountains bounding the Appalachian Valley on the southeast in Adams and Franklin counties. Local usage, however, is followed rather than the proposal of a new name or the restoration of uncommon names.

As shown on the map, few generalizations can be made concerning the size, shape, height or direction of the hills of this province. Elongation in a west-southwest direction and separation by narrow valleys of like trend is noticeable although there are exceptions. Some of the ridges are several miles long; some hills are isolated, rounded. Flat-topped eminences are lacking and no correlation of the hill tops can be made. East of the Delaware River in New Jersey and continuous with this section is the fairly flat-topped Schooley Mountain. Presumably, at one time such a feature may have been present in Northampton County but it has now disappeared by differential erosion.

Some hill tops exceed 700 feet elevation and two rise above 1,000 feet. The slopes of the mountains are generally covered with talus, in some cases extremely large blocks. The thickness of the talus can seldom be determined, as excavations for new structures on the lower slopes rarely encounter the solid rock in place. Anomalous conditions can be found in the region, such as hard fresh rocks outcropping as steep ledges; rocks weathered in place to such an extent that they can be dug readily with pick and shovel to the depths of 40 or 50 feet; and talus composed of both fresh and decomposed rocks. On the hill slopes in many places excellent examples of spheroidal or concentric weathering (exfoliation) of angular blocks of gneiss can be found. They are as spherical as though they had been rounded by stream transportation.

In many places north slopes are steeper than south slopes. This is explained as the result of frost action. On the northern slopes the soil water may be frozen only a few times during each winter but on the southern sides numerous alternate freezings and thawings each

season have accentuated the results of frost work and the slopes have been reduced.

Triassic Lowlands.—If the physiographic divisions of the region are definitely confined to stratigraphic geologic formations, the division termed the Triassic Lowlands is represented in that segment of Flint Hill that appears in the extreme south corner of Northampton County. If, on the other hand, the separation is made on topographic characteristics, this division is not represented in the county. Flint Hill, topographically, is a part of the Reading Prong of the New England Uplands. The highest point, which lies in Lehigh County, has an elevation of 1,006 feet. It owes its height to the erosional resistance of the Brunswick conglomerate of which it is composed. It stands from 300 to 500 feet higher than the general level of the Triassic Lowlands physiographic division and is not characteristic of the division. It is a fairly circular hill, slightly longer in an east-west direction, with the northern slopes considerably steeper than the southern, mainly too steep for cultivation.

Origin of the Physiographic Features

In the explanation of the physiographic divisions just described, the limitation of space precludes the evaluation of each of the contributions that have been made and it seems inadvisable to do more than name the persons who have contributed to this problem. An attempt has been made to include all the published researches in the Bibliography and the reader is referred to that chapter for titles and places of publication. The most important articles have been written by J. P. Lesley, F. Prime, W. M. Davis, R. D. Salisbury, J. Barrell, D. W. Johnson, M. R. Campbell, G. W. Stose, F. Bascom, E. B. Knopf, A. I. Jonas, G. H. Ashley, K. Ver Steeg, F. Ward, W. S. Tower, E. W. Shaw, N. M. Fenneman, H. A. Meyerhoff and E. W. Olmsted. It would be difficult to decide which of these deserves most credit and the order in which they have been mentioned means nothing. Several are in general agreement although probably no two are in complete agreement.

Formation of the Schooley peneplane.—Probably all the investigators believe that at some time in the past all this region and most of the entire Appalachian belt of eastern United States was reduced to a base level of erosion that was near sea level. This occurred long after the Appalachian Revolution had thrown the original horizontal rocks into great folds by which certain portions were uplifted thousands of feet above other sections. The base level of erosion was developed by the truncation of the tops of the folds and the formation of a featureless plane with little or no distinction between hard and

soft rocks. Across this plane sluggish streams took their winding courses to the Atlantic Ocean.

The next event was an uplift of the entire region without folding or major faulting. The movement is believed to have been almost vertical. It was not equally great in all places, with the result that the old erosion surface was somewhat warped.

The date of this extensive peneplanation has been assumed generally to have been during Cretaceous time and the debris removed by the streams was deposited in the nearby Atlantic Ocean. This debris forms the extensive Cretaceous strata of the Coastal Plain. In recent years the idea of a much younger age has been advanced until now Ashley[3] regards the peneplanation to have been completed no longer ago than late Pliocene time. Strong arguments are presented in support of his view. At this time the date of peneplanation may be said to be undetermined.

Another new conception of past events which essentially alters the older ideas was suggested by Barrell and recently elaborated by Johnson.[4] He suggests that peneplanation was followed by a submergence and the deposition of a mantle of coastal plain sediments covering a large part, if not all, of the peneplane. He presents an array of facts to show that the present drainage system can best be explained by a former cover of this sort. The present streams are believed to have originated when the region was later uplifted. They eventually cut through these unconsolidated sediments and, maintaining their positions, cut channels in the underlying Paleozoic rocks. This explains the manner in which the major streams cut across both hard and soft rocks alike with little regard to structures. Johnson's theory is beyond proof or denial as no trace of the extended coastal plain sediments remains. It appeals to some geologists but as yet seems to have been received with much skepticism.

Ver Steeg[5] presents one bit of evidence as opposed to this idea of a cover of coastal plain sediments.

> In the majority of cases it was found, as a result of profile and field studies of Appalachian ridges in Pennsylvania and New Jersey, that for long distances on either side of water gaps and major wind gaps, ridge crests representing the upper (Schooley or Kittatinny) peneplane descend faintly toward the major stream courses, indicating that these streams were superposed in a cycle earlier than the Schooley (Kittatinny) and held their courses throughout Schooley (Kittatinny) time. . . . The presence of high level, broad, shallow valleys on the Schooley (Kittatinny) peneplane, coincident with the present courses of the larger rivers, is not consistent with the theory that these streams were incised in this peneplane from an immediately overlying coastal plain cover. (p. 218.)

[3] Ashley, G. H., Geol. Soc. Amer. Bull., vol. 46, pp. 1395-1436, 1935.

[4] Johnson, D., Stream Sculpture on the Atlantic Slope. 142 pp., 1931.

[5] Ver. Steeg, H., Annals New York Acad. Sci., vol. 32, pp. 87-220, 1930.

The name Kittatinny was long applied to this peneplane of erosion. Kittatinny Mountain, with its comparatively flat top caused by the truncation of steeply dipping hard siliceous rocks to about the same level, has been assumed to constitute the existing remnants of this old plane. It is now generally believed that the peneplane developed on Schooley Mountain is likewise a part of this old base level plane. It is at a lower level but the dip of the plane to the southeast, it is thought, would bring the two together if the intervening low lying region could be refilled to its former condition. Stose[6] correlated the Kittatinny and Schooley peneplanes and suggested a post-Cretaceous normal fault to account for the differences in level of the tops of Kittatinny and Schooley (N. J.) mountains. Other workers do not consider such a hypothesis necessary. The peneplane of Schooley Mountain was earlier named the Schooley peneplane and therefore gains priority over Kittatinny. Accordingly, if one name is dropped it must be the later one and we therefore adopt the name of Schooley peneplane for the flat truncated surface of Kittatinny Mountain.

In most of the published articles it is assumed that the present top of Kittatinny Mountain is substantially the same surface as that developed during pleneplanation. Ashley[7] has presented evidence to support his belief in a great reduction by erosion during the period of time since the uplift of the Schooley peneplane. He estimates a reduction of hundreds of feet, perhaps as much as 1,200 feet. Dr. Ashley has called attention to an oversight of former workers and a very important one, yet the writer is not at this time able to reconcile this great reduction with the even surface now remaining. If the strata were homogeneous in composition and structure, one might believe that they would be reduced in such uniformity as to preserve the old peneplane characteristics. However, the variations in both composition and structure are too great for him to believe that Kittatinny Mountain has been lowered a thousand feet or even a few hundred feet below the old Schooley peneplane. As he has viewed and admired from the Lehigh University campus day after day for over thirty years the even skyline of Kittatinny Mountain on the distant horizon, he has speculated on its origin and is still inclined to believe that the top of the mountain, especially where it preserves a flat surface from a fourth to half a mile in width, has not been substantially lowered from the old Schooley peneplane surface. The fresh appearance of the glacial striæ on some of the hard ledges on the crest of the mountain east of Fox Gap bears witness to the slow rate at which these strata are being destroyed.

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[6] Stose, George W., Possible post-Cretaceous faulting in the Appalachians: Geol. Soc. America Bull., vol. 38, pp. 493-504, 1927.
[7] Ashley, G. H., op. cit.

The Schooley peneplane is not observable in the South Mountains in Northampton County. They seem to have been reduced below the old peneplane surface and at varying amounts. The higher points may be only slightly below but they fail to preserve any of the peneplane features.

Formation of the Harrisburg peneplane.—Disregarding Johnson's theory of a marine submergence of the Schooley peneplane, we may continue the story following the vertical elevation. The uplift resulted in renewed activity of the streams and more rapid removal of the products of weathering. Under such conditions, the less resistant rocks were the ones that suffered most. The first uplift of the peneplane was of the magnitude of 700 to 900 feet. Eventually all the softer rocks, the limestones and slates, are believed to have been lowered to a new base level whereas the crystalline rocks of South Mountains and the hard siliceous rocks of Kittatinny Mountain suffered little reduction.

This second peneplanation, which was only a partial one, embraced only that area between Kittatinny Mountain and the crystalline rock portions of the South Mountains. This is the peneplane represented by the level surfaces of the slate region and has been named the Harrisburg peneplane from its development in the Harrisburg region. Later, Campbell,[8] who had originally proposed the name Harrisburg, has suggested the term Chambersburg for this peneplane because of confusions that have resulted. In this volume, however, the original name is retained for the present.

The sandy strata of the middle member of the Martinsburg formation were not entirely reduced to the new base level and they now appear as hills rising noticeably above the Harrisburg peneplane. Miss Bascom[9] suggests that these elevations constitute the remnants of an intermediate base level which she designates the Honeybrook peneplane. In this region particularly there seems to be insufficient evidence for the existence of such a wide-spread plane of erosion between the Schooley and the Harrisburg.

Formation of the Somerville peneplane.—Renewed uplift once more rejuvenated the streams and increased the removal of material from the region. The limestones, because of their destruction by both physical and chemical agents, are the ones which suffer most, and the limestone areas are the first to be reduced to base level. It is believed that they were so lowered to a new base level whereas the slates and harder rocks still preserved the original characteristics of the Schooley and Harrisburg peneplanes with only minor changes. A further uplift

[8] Campbell, M. R., Chambersburg (Harrisburg) Peneplain in the Piedmont of Maryland and Pennsylvania: Geol. Soc. Amer. Bull., vol. 44, pp. 553-573, 1933.

[9] Bascom, F., Jour. of Geol., vol. 29, pp. 540-559, 1921.

occurred before the base level had been extended and the slates and other harder rocks lowered to the new base level developed in the limestone areas.

The peneplane developed on the Cambrian and Ordovician limestones of the region, and on which portions of Bethlehem and Easton are built, is known as the Somerville peneplane. At times it has locally been called the Bethlehem peneplane. The features of this peneplane have been described on an earlier page. It is of much less extent than either of the other peneplanes and, being younger, has undergone less change subsequent to its formation.

Are There One, Two or Three Peneplanes in Northampton County?

In the foregoing pages, descriptions have been given of three separate and distinct pleneplanes. This is the view held by the writer although he recognizes the value of the arguments advanced by other workers who interpret the existing topographic features differently.

There has been repeated questioning of the existence of the Somerville peneplane. The writer, himself, for several years maintained that the development of this flat surface of erosion did not result from any uplift of the region and subsequent reduction by stream action, but was simply the lowering by solution of that portion of the Harrisburg peneplane underlain by limestones. Ward[10] has furnished an excellent discussion of the problem.

The fact that the Somerville peneplane is distinctly limited to the limestone areas is the principal argument against the generally accepted view. In addition, the numerous examples of solution such as sink holes, underground channels and caves and the absence of stream gravels over the uplands furnish corroborative evidence.

The evidence for the Somerville peneplane of fluvial erosion accompanied by solution and the development of a base level of degradation is the regularity of the surface. The various rocks in which the plane has been cut have been folded, faulted and shattered locally to a remarkable degree. The writer doubts that the region could have been so regularly reduced by solution alone without base leveling. These variables must have influenced the rates of lowering by the underground circulation and should have developed a much more irregular surface than now exists. Of course, no one will deny that solution has been an important agent. The question does not admit of a positive decision and it is expected that different points of view will continue.

[10] Ward, F., The role of solution in peneplanation: Jour. of Geol., vol. 38, pp. 262-270, 1930.

Recently, Ashley[11] has proposed the elimination of all but the Schooley peneplane of fluvial base level erosion. He believes that all the present topographic features are the result of differential erosion. The Cambro-Ordovician limestones were least resistant, the Martinsburg slates somewhat more and the Shawangunk conglomerates and sandstones most. Therefore, the surfaces described as the Harrisburg and Somerville peneplanes do not imply different stages of base-leveling and subsequent uplifts.

A similar objection to that offered for the elimination of the Somerville peneplane of stream erosion (and solution) can be advanced against Ashley's proposal. With the complicated structures and varying hardness of the strata of both the Martinsburg slates and the Cambro-Ordovician limestones, it does not seem to the writer that differential erosion unaccompanied by fluvial erosion base-leveling would have developed the even surfaces of the uplands over extensive areas such as are present in this district. Further, the entrenched meanders that are conspicuous in the shale areas in many places in the State and in some localities in the limestones imply the development of meandering streams on a more or less peneplaned surface, followed by uplift and entrenchment. These are well seen in Northampton County, especially near Kreidersville and Treichlers.

It is left for the individual reader to choose the explanation which most appeals to him as the correct one. All will agree that all surfaces, no matter how flat, are being lowered and modified continually but whether the existing level surfaces lower than the Schooley peneplane have been developed by differential erosion or by several periods of base-leveling and broad crustal uplifts is the question. It is receiving serious attention at the present time.

Before leaving the question of peneplanation, it may be well to make reference to the hypothesis proposed by Barrell[12] in 1913 and on which he was at work at the time of his death in May 1919. His uncompleted manuscript was published[13] after his death. He suggested that the level surfaces described as peneplanes of fluvial erosion may have been the result of marine denudation at times when the ocean transgressed the continent to a greater extent than generally believed. This idea has not received much support. One can not know what Barrell's final conclusion may have been but with the keen analytical mind which he possessed it is thought that he would have made important contributions. He began his geological investigations while a

[11] Ashley, George H., Studies in Appalachian Mountain sculpture: Geol. Soc. of Amer. Bull., vol. 46, pp. 1395-1436, 1935.
[12] Barrell, Joseph, Geol. Soc. of Amer. Bull., vol. 24, pp. 688-696, 1913.
[13] Barrell, Joseph, Amer. Jour. of Sci., 4th ser., vol. 49, pp. 227-258, 327-362, 407-428, 1920.

student in Lehigh University and was well acquainted with the geomorphological problems of this region.

STREAMS*

The drainage of Northampton County is effected by two major streams, the Delaware and Lehigh rivers, and their tributaries. Practically the entire area is well drained, although there are some localities within the limestone regions where there is no surface run-off. The water there flows underground in solution cavities. There are a few small swampy areas in the slate regions, especially in the northeastern part of the county where the glacial deposits are especially prominent.

Delaware River

The Delaware River is one of the most important streams of Pennsylvania although it receives only 14.3 percent of the drainage of the State. It drains an area of 12,012 square miles of which 6,460 are in Pennsylvania. The east and west branches head in the Catskill Mountains and unite at Hancock, N. Y., on the Pennsylvania-New York boundary. The length of the main river to the Delaware State line is 248 miles. The gradient in the upper course, from Hancock to the Northampton County line, averages 5.29 feet per mile; from the Delaware Water Gap (elevation, 290 feet above sea level) to Easton (elevation 157), a distance of 29 miles, it is 4.6 feet per mile; below Easton it decreases, averaging 3.11 feet per mile, to tide water at Trenton. The gradient is not uniform and the velocity varies in different portions. In several places, particularly at Foul Rift and at the Weygadt just above Easton, hard rock ledges obstruct the stream and produce rapids which have long been difficult to navigate with canoes. Elsewhere the gradient is so low that deposits of alluvium have accumulated to form bars and low islands. Some of these islands are of considerable size and have existed so long that they are forested and in part cultivated. They are subject to flooding at times of high water and occasionally undergo diminution by erosion or accretion by deposition, thus changing their shape and size.

The Delaware River as it flows along the borders of Northampton County is not now regarded as navigable. For many years it was used for rafting logs and lumber to Philadelphia. In 1791 some of the rock ledges in the river at Foul Rift were removed to facilitate their passage. Also for a time some small boats from Philadelphia and Trenton ascended the Delaware River as far as Easton. Dr. B. F.

* Much of the following matter has been taken directly or abstracted from an exhaustive investigation of the water resources of the State in 1916-1920 by the Water Supply Commission of Pennsylvania and published in 10 parts (see Bibliography).

Fackenthal[14] has published an exhaustive report on the utilization of the Delaware River.

Terraces are well-developed in certain places along the Delaware River in Northampton County. They are very level except where stream erosion has dissected them. Two of the terraces are conspicuous topographic features; remnants of a higher one are noted in a few places. They are terraces of deposition and have furnished considerable sand and gravel for local use. The best illustrations of these terraces are between Riverton and Martins Creek. The lower terrace is from 200 to 240 feet above sea level. The higher, broader one, over which the Belvidere highway passes, lies from 300 to 340 feet above sea level. Similar terraces with slightly greater or lower elevations, depending upon whether they are up or down stream from this locality, occur in several other places. Terraces are lacking where the river is cutting on the right bank or has done so recently, resulting in steep rock walls bordering the stream.

Lehigh River

The Lehigh River, rising in the Pocono Plateau of Wayne County, is about 100 miles long. It receives the drainage of the entire western half of the county. In its upper course, above the Lehigh Gap, it is a rapid stream with high bordering hills, but in its course through Northampton County it has a moderate gradient. From Slatington to Allentown, a distance of 17 miles, the river descends 113 feet, or 6.65 feet per mile. From Allentown to Easton, 16.5 miles, it descends 68 feet, or 4.12 feet per mile.

As it flows through the slate region to Northampton it has a rocky bed in many places. Thence to Easton it passes through limestone and has a deep fill of alluvial matter. A number of alluvial islands are present below Northampton. These islands are mainly covered with trees of considerable size, furnishing evidence of their age, although at times of high water the islands do undergo some modification by erosion and deposition. Small bungalows built on some of these islands can not be used permanently owing to overflow at times of high water.

At Bethlehem a thickness of forty feet of alluvium in the river channel indicates an over-deepening at one time. Part of the fill consists of very course material with boulders as much as two feet in diameter. It is possible that the Bethlehem portion of the county was warped upwards while the thick ice sheet in the Pen Argyl district depressed the northeastern part of the county. When the ice melted the former

[14] Fackenthal, Jr., B. F., Improving navigation on the Delaware River with some account of its ferries, bridges, canals and floods: Bucks County Historical Society, vol. 6, pp. 103-230, 1932.

conditions were restored. As the Bethlehem area sank to its normal elevation, the deepened river channel was filled. In Lehigh County, Jordan Creek has similarly a fill of forty feet of alluvium. It is hoped that more data of this kind can be secured; then more positive explanations can be offered.

Eight dams have been constructed across the Lehigh River between the Lehigh Gap and Easton in order to effect navigation by the canal boats that transported anthracite from the coal regions to Philadelphia and towns between for over 100 years. The boats navigated the open river in places but in other places the canal dug beside the river. At present the canal is used only to furnish a small amount of water power at several places.

The Lehigh River receives some drainage from the anthracite districts and the black silt along the banks contains coal that has been carried from the culm banks and washeries of the coal mines. One can easily recognize coal particles in many places and occasionally, as far down as Bethlehem, thin streaks or small pockets of almost pure coal can be found.

A recent report[15] based on a special survey of the rivers of Pennsylvania, describes the fine-coal dredging operations along the Lehigh River. Three of these lie partly within Northampton County. They are confined to the region above the Lehigh Coal & Navigation Company dams at Lehigh Gap, Three Mile Dam below Walnutport and the Treichler Dam at Laurys Station. The dredgers pay a royalty of fifteen cents per ton to the Navigation Company. The coal, when separated from the sand by screens and tables, is of good quality. The quantity obtainable varies with the seasons. Each flood brings down new supplies.

The Lehigh River throughout most of Northampton County is in early maturity. Flood plains of considerable width are developed on one or both sides at many points. On these flat lands bordering the streams many residences and establishments have been built but the major portions of the river towns are on the higher ground. Railroads and highways follow well developed flood plains on both sides of the river across the county. In the construction of the railroad lines and highways it was necessary to remove considerable rock in some places but not an excessive amount.

The principal tributary streams of Northampton County and their drainage areas are as follows:

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[15] Comprehensive Studies and Analyses, Coal and Sand and Gravel Dredging Industries, Department of Forests and Waters of the Commonwealth of Pennsylvania, 173 pp., 1936.

Name of creek Delaware River tributaries	*Drainage area in square miles*
Slateford	3.2
Jacoby	5.6
Allegheny	8.7
Oughoughton	11.0
Martins	46.7
East Fork	2.3
West Fork	3.3
Waltz	12.4
Little Martins	6.3
Mud Run	5.9
Bushkill	74.8
Schoeneck	14.4

Name of creek Lehigh River tributaries	*Drainage area in square miles*
Hokendauqua	42.0
Indian	14.2
Dry Run	2.5
Catasauqua	14.6
Monocacy	49.6
East Branch	16.9
Saucon	58.2
Black River	4.4
East Branch	9.6
Nancy Run	2.8

These tributary streams may be divided into two classes with reference to the kinds of rock in which they have cut their valleys and the resulting characteristics. Those confined to the slates have steeper gradients, deeper and narrower valleys and fairly uniform valley slopes. On the other hand the streams of the limestone sections are just the reverse—gentler stream gradients, shallow open valleys or in places steep jagged rock walls. Those of the slate regions maintain a steadier flow and seldom become entirely dry. The streams of the limestones are apt to disappear during periods of drought, the diminished supply of water sinking into underground solution channels. In some years high weeds grow in the limestone bed of the Monocacy Creek between Bath and Camels Hump in the late fall whereas the creek in the slate region is rarely dry.

Several of the streams in the above list have their head waters in the slate regions and their lower courses in the limestones. They present striking dissimilarities in their upper and lower portions. The Bushkill, Catasauqua and Monocacy creeks are good examples.

Martins Creek has a length of about fifteen miles and an average gradient of 45.7 feet per mile, gradually becoming less toward its mouth.

Bushkill Creek is about twenty miles in length with a fall of 24.2 feet in the lower nine miles of its course. Monocacy Creek is about eleven miles long. The lower five miles has a fall of 11.4 feet per mile and the next five miles is 40 feet per mile.

Saucon Creek has a length of 16.5 miles with the upper portion in Lehigh County. It is confined to the limestones of Saucon Valley. The lower 12.5 miles has a gradient of 15.5 feet per mile.

Floods of the Delaware and Lehigh Rivers

There are many historical accounts of great floods and droughts in the Delaware and Lehigh rivers. At different times accurate measurements have been taken over considerable periods. In certain localities

high-water marks have been made on buildings at times of flood and these elevations later determined. A great mass of information is available, most of which is fairly reliable.

Since 1888 the U. S. Geological Survey has been engaged in accurate measurements of the principal streams of the United States and the results have been published in annual Water Supply Papers, in Bulletins, Professional Papers, Monographs and Annual Reports. In recent years the Division of Hydrography of the Pennsylvania Department of Forests and Waters has cooperated in this work. An annual bulletin of Stream Flow Records is issued and in addition in 1916-1917 an elaborate Water Resources Inventory Report was published by the State.

Of pertinent value to this region are the stream gage data obtained at Belvidere (N. J.), Easton-Phillipsburg (N. J.), and Riegelsville (just below the boundary of Northampton County) on the Delaware River and at Bethlehem on the Lehigh River. A record of floods on these streams has been compiled. A gage height of fifteen feet usually results in a flood of sufficient magnitude to effect some damage. Therefore, the table lists all known floods in which such a height was attained.

Since the zero or datum plane is selected somewhat arbitrarily, the elevations above sea level are important. At Belvidere the datum plane is 227.18 feet above sea level. At Easton the datum plane of the gage between 1777 and 1814 was 164.4 feet; from 1841 to 1903 it was 155.8 feet; and later than 1903 it was 157.2 feet above sea level. At Riegelsville the gage zero is 125.29 feet above sea level. At Bethlehem the datum plane before 1909 was 213.45 feet above sea level; from 1909 to 1928 it was 210.64 feet and since 1928 it is 208.50 feet above sea level. These variations in datum plane are mainly due to the locations being moved either up or down stream. In every case a datum plane has been selected that is a foot or two below the lowest water known to have been reached even in the most disastrous droughts. The figures given are within close limits of what would have been obtained if the gage locations and gage zeros had remained constant during the entire time.

An examination of the following tables shows that the known maximum stage of the Delaware River at Belvidere was 28.6 feet on October 10, 1903. At that time the river had a discharge of 220,000 second-feet. The minimum known stage at that place was 2.37 feet on September 28, 1932 with a discharge of 838 second-feet. At Easton the maximum high water occurred on October 10, 1903 and was 35.9 (or 36.7) feet as determined by high water marks. At Riegelsville the maximum stage was recorded in the same day and was 35.9

Major floods of the Delaware and Lehigh Rivers
(gage heights exceeding 15 feet)
Height of gage in feet*

Date	*Delaware River*			*Lehigh River*
	Belvidere, N. J.	*Easton-Phillipsburg*	*Riegelsville*	*Bethlehem*
1747, Feb. 28				?
1777, Oct. 27		23.2		?
1781, May 9		25.5 (21.0)		
1783, Feb. 28		24.4 (20.0)		
1785, Mar. 17		26.9 (23.0)		
1786, Oct. 4		25.2 (21.0)		18
1814, Apr. 1		24.4 (20.0)		
1832, Mar. 13		15.0±		
1836, Apr. 11		21.6±		
1839, Jan. 26				16
1841, Jan. 8		32.2 (28.5)		23
1845, Oct. 13		22.6		
1846, Mar. 16		27.8 (24.0)		
1857, May 3		24.3		
1862, June 5		32.1 (28.5)		23.3
1868, July 20		24.8		
1869, Oct. 4				23
1869, Oct. 15		28.6 (24.5)		
1875, Apr. 9		27.5 (23.5)		
1878, Oct. 27		22.6		
1878, Dec. 11		28.6 (24.5)		
1882, Mar. 2		23.1		
1885, Apr. 14		21.0		
1886, Jan. 3-4		18.0		
1886, Feb. 14		23.2		
1886, Apr. 1		21.2		
1886, June 6		20.2		
1888, Sept. 18		22.1		
1893, Mar. 12		21.0		
1894, May 21				17
1895, Apr. 9		27.5 (23.5)		
1896, Mar. 1		20.0		
1900, Mar. 2		20.0		
1901, Dec. 15-16		31.1		17.5
1902, Feb. 28				25.9
1902, Mar. 2		29.5		
1903, Oct. 10-11	28.6	36.7 (35.9)	35.9	
1906, Apr. 16		16.2		
1907, Dec. 11		18.2		
1908, Feb. 16		18.5		
1909, Feb. 21		16.6		
1910, Jan. 23		17.5		
1910, Mar. 2		17.0		
1913, Mar. 28		22.2	25.0	
1914, Mar. 29		21.0		
1915, Feb. 26				16.8±
1916, Mar. 31-Apr. 4			19.3	
1918, Mar. 28			18.4	
1920, Mar. 14			19.8	
1921, Mar. 9-11			21.0	
1921, Nov. 29			20.4	
1923, Mar. 24			17.8	
1924, Apr. 7-8	18.02		23.1	

* The first figures given are those published as recorded. In parentheses are given figures referred to the present Phillipsburg gage. Some discrepancies may be seen which are not explainable.

Major floods of the Delaware and Lehigh Rivers—Continued
(gage heights exceeding 15 feet)
Height of gage in feet

Date	Delaware River			Lehigh River
	Belvidere, N. J.	Easton-Phillipsburg	Riegelsville	Bethlehem
1924, Oct. 1	19.3	22.0	24.2	16.2
1925, Feb. 12		21.0		
1926, Nov. 17	18.5		22.6	16.5
1928, Oct. 20	16.8		21.3	
1929, Mar. 15-16	15.9		18.3	
1932, Apr. 2			15.76	
1933, Aug. 24-25	19.90	25.0	25.0	20.8
1934, Mar. 6	17.22		18.2	
1934, Dec. 2	15.03			
1935, July 10		20.0	23.20	20.7
1936, Mar. 12				19.0
1936, Mar. 19	25.0	30.7	32.45	

with a discharge of 275,000 feet. The minimum height known, not including the flow in the canal, was measured on September 20, 1908. It was 1.55 feet with a discharge of 870 second-feet.

The maximum height of the Lehigh River at Bethlehem was 25.9 feet on February 28, 1902 with a discharge of 92,000 second-feet. The minimum stage known was 1.33 feet on October 15, 1910 with a discharge of 160 second-feet.

It will be noted that there have been floods in every month of the year but with more in March. The other winter months, December, January and February, have also had a number of floods. Practically all of these were caused by a combination of heavy rainfall and rapid melting of snow and ice over the drainage areas. At times ice jams have greatly increased the height of the water. The high water periods of April and October are explained by heavy wide-spread spring and fall rains. The late summer floods have occurred when a West Indian hurricane coming up the Atlantic Coast has passed slowly over the region with excessively heavy precipitation for several days in succession.

In the local histories and newspapers there are accounts of disastrous floods during the early history of the region but with few exact figures. During the 200 years since the settlement of the region there has been much destruction of property and some loss of human life. Residences, factories, railroads and highways have been built within the danger zone so that there is bound to be considerable property damage whenever the streams rise to flood stage. The destruction was greater in the early days when all the structures were of poorer grade than at present. In the 1841 flood all the Lehigh River bridges,

which were entirely wooden, from Mauch Chunk to Easton were destroyed. The limitations of space forbid the description of the individual floods.

The tables show that the floods of the Lehigh and Delaware rivers do not always occur at the same time. This is due to the fact that occasionally the conditions causing the high water are not the same in the two drainage areas.

At this time of writing (February 1938) plans have been formulated for a system of flood control along the Lehigh River between Laurys and Easton. A detailed topographic survey has been made of this portion of the Lehigh River channel and flood plain between these points, under the supervision of the U. S. Engineer Office of the War Department.

Evolution of the Drainage System

The development of the present drainage system of Northampton County is linked up naturally with the evolution of the streams of the entire eastern portion of the United States. (Fig. 29) A full discussion leads one far afield and obviously does not properly constitute a part of this volume. It is highly theoretical in the main and probably always will be.

There is little disagreement among geologists regarding the existence of northwestward flowing streams during the Paleozoic era, by which sediments from the ancient continents were carried into the great interior sea. Following the Appalachian revolution the drainage direction was reversed. The Atlantic Coastal Plain is composed of the materials removed from the uplifted and folded regions lying to the northwest and west.

The present drainage system is believed to date from the uplift following Schooley peneplanation, or, according to Barrell and Johnson, from the elevation following the deposition of Coastal Plain sediments on top of the Schooley peneplane. Most geologists agree that the major streams following this uplift flowed to the southeast. The existing major streams of eastern Pennsylvania now have a general southeasterly course but in certain portions of their courses turn sharply to the northeast or southwest, parallel to the structures of the hard rock ridges of the folded mountains. These abrupt changes in course indicate plainly that there have been adjustments in the original streams. Much speculation as to what has been their history has resulted. Davis (1889), Walter (1895), Williams (1902), Johnson (1931), Ver Steeg (1930) and Itter (1936) (see Bibliography) are the principal writers on this problem. Most of them believe that the southeasterly-flowing portions of the existing streams are original

A. Delaware Water Gap from the south.

B. South part of Delaware Water Gap from New Jersey side. Contact of Martinsburg and Shawangunk concealed by talus.

C. Pen Argyl Wind Gap from the south.

features, and that adjustments to geologic structures have been accomplished by stream piracy and dismemberment of old streams. The presence of shale and limestone valleys between the resistant rock ridges has especially favored such processes. The changes which affect the streams of Northampton County only can be considered here.

Williams[16] has offered an explanation of the change of course of the Lehigh River at Allentown. He believes that originally the Lehigh from Lehigh Gap flowed south or southeast until the vicinity of Allentown where it turned to the southwest, passed through Leipert's Gap near Emmaus, Lehigh County, and continued to the Perkiomen Valley. He thinks that a westward-flowing tributary existed along the north side of South Mountain from Freemansburg or beyond and joined the Lehigh in the Allentown region. Monocacy Creek is thought to have been a tributary of this stream and instead of its present course, it turned to the southwest in the north part of Bethlehem and crossed the present highest portion of west Bethlehem. This filled valley has been partially located by well borings. He supposed that a tributary of the Delaware River flowing past Glendon pushed its head westward until eventually it captured the Lehigh River at Allentown. This theory is worthy of examination although it has not generally been accepted.

Johnson, Ver Steeg and Itter have presented the most complete discussion of the changes of drainage of the Lehigh and Delaware. They think that the North Branch of the Susquehanna River once flowed to the southeast, through Wind Gap and approximately along the present course of the Bushkill River to the vicinity of Easton and thence along the course of the present Delaware River. By stream piracy, aided by rock structures, the head waters of this major stream were diverted westward through the Wyoming Valley, and other portions north of Kittatinny Mountain were captured by tributaries of the Delaware and Lehigh rivers. Raritan River is thought to have headed in the vicinity of the Delaware Water Gap whereas the Delaware River was a parallel southeasterly-flowing river to the northeast. By adjustments the Delaware was turned southwestward along the north flank of Kittatinny Mountain to Delaware Water Gap whence it turned southward.

It is not possible either to prove or disprove these theories but they do tend to make clear some of the otherwise anomalous characters of these major streams. The wind gaps and water gaps of adjoining regions are also taken into consideration in the full discussion of the problem.

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[16] Williams, Jr., E. H., Bull. Geol. Soc. of Amer., vol. 5, pp. 281-296, 1894; Proc. and Coll. of Wyoming Hist. and Geol. Soc., vol. 7, pp. 21-28, 1902.

In several other places in Northampton County there are suggestive evidences of similar adjustments of the minor streams. It is a fascinating subject for investigation and should receive further consideration. The writer believes that there is an old buried valley extending eastward from Green Pond, another one in the same direction southeast of Nazareth, and possibly others. Geophysical work is now being planned to supplement the data obtained from well borings, with the hope that some of these suppositions may be either proved or disproved.

Water Gaps of Kittatinny (Blue) Mountain

A water gap is a short, narrow, steep-sided pass or gorge by which a stream cuts through a hard, resistant rock ridge. A wind gap is an abandoned water gap or notch in a ridge cut by a stream that was later diverted or captured. Examples of wind and water gaps are numerous throughout the folded Appalachians of Pennsylvania; those partially within Northampton County are especially noteworthy.

These gaps afford such excellent stratigraphic and structural sections that the writer requested Dr. Bradford Willard, who has made detailed studies of these phenomena, to prepare the sections and descriptions which are published in a separate chapter of this volume. His descriptions supplement this discussion. His sections extend beyond the confines of Northampton County but this seems advisable for the benefit of geologists visiting the regions.

The origin of these gaps has long received the attention of both the traveler and the geologist. Many are the descriptions that have been published. A few extracts are quoted.

Delaware Water Gap[17]

The great geological phenomenon bearing the above expressive though not very euphonious name, is one of the most striking scenes in our country, and is a subject upon which volumes might be written. The chain of mountains known in general terms as the *Blue Ridge*, ranging nearly parallel with the Atlantic coast, and having its rise in New Hampshire and terminating in the extreme Southern States, has, in each State through which it passes, some distinguishing feature, as the *White Mountains* in New Hampshire, *Green Mountains* in Vermont, *Catskill* in New York, *Harper's Ferry* in Virginia, and the *Delaware Water Gap* in Pennsylvania and New Jersey.

The waters of the Delaware at this point approach the mountain with a gentle current, and gracefully sweeping from the north toward the east, turn suddenly and pass through the Blue Ridge, cutting it to the base, while its ragged, sloping sides towering up to an elevation of 1,600 feet, frown down upon the river as it calmly pursues its course toward the ocean.

Whether this immense chasm has been caused by one mighty eruption, or by a gradual yielding of stratum after stratum, by the immense pressure of the waters of a lake thousands of acres in area, down to the present bed of the river; or by the active dissolution of the material upon which the

[17] Brodhead, L. W., Delaware Water Gap: Its Legends and Early History, pp. 16-20, Philadelphia, 1870.

foundation of the mountain rested, burying the whole mass deep in the gulf thus created, is of course a subject of mere conjecture, and can never be satisfactorily determined. The depth and solidity of the stratification on either side of the chasm would seem, however, to favor the first hypothesis.

The evidences of the action of water on rocks hundreds of feet above the present level of the river-bed, and the masses of drift forming isolated hills and alluvial banks, indicate lake-like repose in the country now drained by the tributaries of the stream above the great gate in the mountain barrier.

The Indian name of *Minisink*—meaning "the water is gone"—given by the aborigines to the level country north of the Gap, and extending up the river many miles, would seem to indicate some tradition confirming the theory of a lake at some remote period of time.

The mass of matter thrown out from this chasm must have deluged the whole country south of the "Gap" for many miles in extent; but we shall, perhaps, never find a *Herculaneum* or a *Pompeii* buried beneath the accumulated debris, although some future *Boucher de Perthes*, delving deep in the bowels of the earth for evidences of prehistoric man, may here find some relic of the *stone age*, very like those now so plentifully found upon the surface.

The two following paragraphs, giving an estimate of the probable amount of matter thrown out of the opening forming the "Gap," etc., are extracts from a letter written by the author of this book, some years ago, for the *New York Sun*, portions of which were afterward published in a History of Northampton and Monroe Counties:

Estimating the height of the mountain on either side at 1,600 feet, the width of the space or distance between the mountains at half their height to be 1,000 feet, the whole distance through at one mile, would give the enormous amount of 8,451,600,000 cubic feet, a sufficiency of matter to overwhelm a township of ordinary size to the depth of five feet.

Here there has been a convulsion that must have *shaken the earth to the very centre*, and the "elements to give signs that all was lost." But He who governs the world and has all things at His command; He who holds the globe by the might of His power, can remove the mountains from their foundations and bury them in the deep, and the great machinery of the universe continue to move and lose none of its functions.

The wonderful phenomena of nature witnessed in every clime, setting at defiance all human theories and human research, seem to exist only to impress us with the majesty of Omnipotence, and our own fallible insufficiency; and the great geological transformations that have taken place in the primary condition of the earth's surface, and the constant mutations still continuing, together with our own wasting lives, admonish us of the instability of all sublunary things, and that ere long,

> "Like the baseless fabric of this vision,
> The cloud-capp'd towers, the gorgeous palaces,
> The solemn temples, the great globe itself,
> Yea, all which it inherit, shall dissolve,
> And, like this unsubstantial pageant, faded,
> Leave not a rack behind."

The Delaware Water Gap may have been so planned from creation. We are told in the beautiful language of inspiration: that, "He putteth forth His hand upon the rocks, He overturneth the mountains by the roots, He cutteth out rivers among the rocks, and His eye seeth every precious thing."

Origin of Delaware Water Gap[18]

The Delaware Water Gap is thirty miles above Easton, and is worth a voyage across the Atlantic to see it. Various are the theoretical conjectures as to the cause of this *rent in the rocks*—disarrangement of the rupic mountain mass. It is a stupendous work, and the "rent" is *chasmaticissimus*.

[18] Rupp, I. Daniel, History of Northampton, Lehigh, Monroe, Carbon, and Schuylkill Counties, compilation by: Harrisburg, 1845, pp. 26-28.

The estimated height of the mountains, on either side, is from 1,500 to 1,600 feet; the width of the space between the two mountains at the base, 1,000 feet; and at the summit, 2,000 feet; the whole distance through the mountain is about two miles. In making an estimate of the *amount of matter* thrown out by the passing of the Delaware, if only one mile in length is taken into the account, would then give the enormous amount of cubic feet to be 12,672,000,000, a sufficiency of matter to cover a township of five miles square, or twenty-five square miles, fifteen feet in depth!

Well might it be said, "Here has been a convulsion that must have *shaken the earth to the very center*, and the elements *to give signs that all was lost*." "But *He* who governs the world and has all things at *His* command—*He* who holds the globe by the might of His power, can remove the mountains from their foundations and bury them in the deep, and the great machinery of the universe continue to move, and lose none of its functions."

Various are the conjectures as to the formative cause of these Gaps in the mountain. "It would seem," says a certain writer, in speaking of this Gap, "from the quantity of alluvial lands above the mountain, that, at some remote period, a dam of great height *here* obstructed the progress of the Delaware. If it had been as high, or half as high as the mountain, it would have raised the water that it might have run into the North River. It probably had an elevation of 150 or 200 feet, forming a lake of more than fifty miles in length, covering the Meenesink settlements. This height must have formed cataracts similar, the quantity of water excepted, to that of Niagara.

"It has been conjectured that this dam was engulfed by some great convulsion of the earth, and the following reasons have been assigned for this opinion: The distance through the mountain is about two miles, within which the river has an average width of half a mile, and the water is as still as a mill-pond, so that a raft will be driven by the impulse of the wind *up* or *down;* and the boatmen report that a *hundred and ten years* ago, no bottom could be found with their longest line.

Had the mountain been worn by abrasion, such a gulf would not have existed, and the bottom of the river *here* would have consisted of the same material which forms the side of the pass; but the bottom is of alluvial mud, and the nucleus of the mountain is of a hard granite, peculiar to the place. It is also well known that alluvial particles, which float in the swift current subsides in the pools; and it has been noted by an accurate observer that the river is always much more muddy, or *rily*, as the phrase is, *above* than *below* the Gap. Hence a proportion of the alluvian carried down the stream must have been deposited in this gulf. Supposing the dam to have sunk 1,000 years ago, and two feet of earth per annum to have been thus deposited, 2,000 feet must thus have been heaped upon the original dam, supposed to have been 150 or 200 feet high."

All are agreed that it was owing to some great cause, a mighty disturbance of elements, which wrought a change in the current, as well as the strata of rock. Professor Rogers maintains, while some hold some vast lake had burst its barriers, that by some mighty convulsion, which produced transverse dislocation in the Appalachian chains, may have caused this rent, or chasm.

Die Lecha Wasser-Kaft,[19] i.e., the *Lehigh Water Gap*, in the Kittatinny, or Blue Mountain, the dividing line between Carbon County and that of Lehigh and Northampton, is so named from the river Lehigh, which steals its way through the Gap, prominently walled on both sides, forms a sublime object of admiration, and presents to the observant spectator, one of the most picturesque prospects in east Pennsylvania. At almost every season of the year, the diversified defile is exceedingly attractive. The writer visited this place in September, 1844. In ascending the eastern bank some hundred feet, the scene heightens in grandeur, and the stream—the beautiful, yet curling, rippled waters of the Lehigh River, add much, nay every thing, to make it impressive beyond oblivion. Though it is seemingly a rugged stream *here*, yet as you follow it in its course, through a fertile region of

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[19] Rupp, op. cit., pp. 113-114.

country, receiving tributaries of different sizes, until itself is a considerable river, before it reaches its silvery recipient, the Delaware. It is in all its ways, as well as at the *Gap*, where it rolls majestically over a rupic bed, and reflecting a sombre shade of the impending mountains, a grand stream.

To return to the *Gap*. The eastern bank is bordered for the distance of about a mile by craggy cliffs, towering to an amazing height, and of forms the most *bizarre*. Between which wall of rocks and the river the road winds along. Hastening to leave these black abodes, which seem to afford shelter to none but the ravenous beasts of the forest, the Lehigh appears eagerly moving on towards the fertile low lands, which succeed in view, on the eastern bank.

Ascending the eastern height, the traveler is amply rewarded for the exertion of climbing from rock to rock, in scaling the pine-covered side of the mountain, by the rich and extensive prospect which the eye then commands. At his feet roll the waters of the majestic stream—on the opposite side is a towering ridge, near the summit of which appears, right opposite, emerging from the surrounding woods, a lonely pile of rocks, whimsically called, "*Die Teufel's Kanzel*," i.e., "*The Devil's Pulpit*," which indignantly suffers but a few blasted pines to shade its sullen brow. At a distance an extensive country, variegated with woods and farms, watered by the meandering Lehigh, and ridge retiring behind ridge, till lost in the faint tints of the horizon, all bursts upon the sight, and fill the mind with sublime ideas of the greatness of the Creator. The shattered rocks, thrown together in wild confusion, and the strata of rounded stones, which are to be met with in passing through the Gap, have given rise to the supposition that the Lehigh, being obstructed in its course by the Blue Mountain, was formerly dammed up into a lake, which at length bursting the barrier, formed the chasm now called the *Lehigh Gap*. The learned have not agreed, as yet, in the decision of this mooted point.

Additional early descriptions of these gaps and weird explanations of their origin are briefly mentioned in the Bibliography chapter.

To account for the origin of water gaps it is not necessary to assume that Lake Ontario or some other lake once extended to Blue Mountain and suddenly burst the barrier, as dams collapse under abnormal water pressure; nor to assume the breaking of a mountain ridge by a great earthquake or the formation of the gap at the time of Creation. With the modern conception of geologic time measured by hundreds of millions of years rather than by hundreds or thousands, we realize the great effects produced by slowly acting but long continued natural forces.

The water gaps of the Delaware and Lehigh rivers are solely the work of the rivers themselves. At the Delaware Water Gap there are grooves, scratches and polished surfaces on the rock walls made by the glacial ice which passed through the gap, but it is improbable that any erosion of consequence resulted from ice abrasion. The rivers at one time flowed across the ridge of hard Shawangunk sandstones and conglomerates at the level of the crest of the mountain or even above the present level. Although these rock strata are very hard, the rolling of cobbles and sand over them by the rivers has cut the notches as by a file. In the case of the Delaware River these cutting tools form great gravel deposits that extend down the river valley to

Philadelphia and beyond. At Phillipsburg, Riegelsville, near Morrisville as well as many other places these deposits have long been worked for ballast and concrete aggregate.

The highest point on Kittatinny (Blue) Mountain now preserved in the vicinity of the Delaware Water Gap has an elevation of 1,461 feet and the river a short distance away is somewhat less than 320 feet. The greatest depth of the river in the gap is not known nor can one determine how much higher the mountain was when the river first started to cut the gorge. As a minimum figure, we can safely say that it has cut a notch over 1,200 feet in depth and possibly even several hundred feet more. The Lehigh River at Lehigh Gap apparently has cut almost exactly the same amount, perhaps a few feet less.

When these two major streams started the cutting, it is probable that they were flowing over a featureless plain either of erosion, the newly formed Schooley peneplane, or of deposition according to Johnson.[20] We assume that this plain had a fairly gentle slope to the Atlantic Ocean, although absolute proof is lacking.

Barrell[21] in his studies in this region noted the change of slope in the profiles of both the Delaware and Lehigh gaps and suggested that they represented alternating periods of uplift and stability. He called the more gentle slopes "facets" and attempted to correlate their lower levels with the floors of local wind gaps. As previously mentioned, Barrell had not completed his investigations at the time of his death.

Ver Steeg[22] in his much more detailed investigations reaches different conclusions as shown in the following quotation.

> Barrell believed that the form of the wind and water gaps might give valuable evidence as to the nature of erosion cycles. He was of the opinion that the facets in their profiles are indicative of still stands of the land, during which peneplanation took place. The present writer believes that the facets are the result of unequal resistance of hard rock beds to erosion. Where there are alternating layers of hard and soft rock which stand at an angle sufficiently low, rock ledges produce facets. As a rule, the more resistant beds project into the gaps, whereas the softer beds weather down to gentler slopes. Where the beds stand at high angles, facets are absent.

Shale and limestones underlying great areas on both sides of Blue Mountain, being much less resistant to erosion, have been removed by tributary streams in much greater volume. To restore the region now composing Northampton County to its pre-water gap condition, it is estimated that we would need to add an average of 300 feet over the South Mountain belt, 400 feet over the slate region and 800 feet over the limestone region. This is an average of about 477 feet for the entire county. These are regarded as the minimum figures. Ex-

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[20] Johnson, D., Stream Sculpture on the Atlantic Slope: 1931.
[21] Barrell, J.: Amer. Jour. Sci., 4th ser., vol. 49, pp. 227-258, 327-362, 407-428, 1920.
[22] Ver Steeg, K.: Annals, New York Acad. of Sci., vol. 32, pp. 87-220, 1930.

pressed in tons, more than 400 billion tons of rock has been carried from the area comprising Northampton County by the Delaware River since it began to cut the gap in Kittatinny Mountain. Some of this material was carried away in solution and entered the Atlantic Ocean. The major portion was sand and silt carried in suspension or rolled along the bottom of the stream. Most of this material likewise was carried to the ocean although some was dropped in the channel or on the flood plains of the lower course of the river.

This question is further discussed under the heading of Wind Gaps.

Some of the water gaps of the Appalachians are cut so slightly below the surface level of the streams that ledges of the harder rock strata can be easily seen at low water periods. This is not the case with the Delaware and Lehigh water gaps. Instead, there is a deposit of alluvial matter in the channels of both of these streams.

At the Delaware Water Gap any observer readily notes that there is an off-set in the ridge; that the Pennsylvania portion is not in line with the New Jersey portion. Plainly, there is a structural change at this point. It is usually explained as a flexure or minor fold such as the Big Offset and the Little Offset although this discordance has also been explained by a cross fault. The writer prefers the flexure interpretation although definite proof is lacking.

Some geologists think that there is evidence of similar disagreement with the trend of the strata at Lehigh Gap. This lack of alignment on opposite sides of the river, however, is slight and is believed to be due to a very minor change in direction of strike produced in the original folding. Elsewhere in the Appalachians similar phenomena have led some geologists to attribute the position of water gaps generally to those places where there are structural changes, either cross folds or faults.

The economic importance of the Lehigh and Delaware Water gaps deserves mention. Three railroads and one highway pass through Lehigh Gap and two railroads and two highways through Delaware Water Gap. On the other hand, the narrowness of the gaps has made it necessary to remove a large amount of rock from the walls to permit the passage of these transportation lines. Until the recent widening of the highway through Delaware Water Gap there were times when the congestion of traffic on holidays was terrific.

The geological sections of the Lehigh Gap, the Delaware Water Gap and the Wind Gap are of general interest. For that reason, Dr. Bradford Willard, who has made special investigations in these localities, has been invited to prepare the following short description. (Plate 5 and Figure 31.)

Stratigraphy and Structure of the Kittatinny (Blue) Mountain Gaps

By Bradford Willard

Kittatinny Mountain forms the northern boundary of Northampton County. It is cut from north to south by three major gaps, Delaware, Wind and Lehigh. In each of these a sequence of Silurian formations is exposed. These consist of the Shawangunk, Bloomsburg, Poxono Island, and, a little to the north, the Bossardsville. Only at the Lehigh is the contact with the underlying Martinsburg of late Ordovician age exposed. There the unconformable relations between the Ordovician and Silurian systems may be clearly seen.

CORRELATION TABLE

Lehigh Water Gap	*Wind Gap*	*Delaware Water Gap*
SILURIAN	SILURIAN	SILURIAN ....
(Concealed)	Bossardsville limestone	Bossardsville limestone ....
	(Concealed)	Poxono Island formation
Bloomsburg red beds.	Bloomsburg red beds.	Bloomsburg red beds.
Shawangunk formation	Shawangunk formation	Shawangunk formation
Clinton member		
Tuscarora sandstone		
ORDOVICIAN	ORDOVICIAN	ORDOVICIAN ....
Martinsburg	Martinsburg.........	Martinsburg.........

Shawangunk formation (Oneida-Medina of earlier workers).—The Shawangunk formation is well exposed along the Pennsylvania and New Jersey sides of the Delaware Water Gap and at the other gaps to the west. The lowest 450 to 500 feet of the formation, whose total thickness at Delaware Water Gap is close to 2,000 feet, consists of massive, quartzitic, dirty-gray sandstone and pebble beds whose phenoclasts are quartz, fairly well rounded and sorted. Occasionally larger quartz pebbles are found, and a few black shale fragments or clay galls occur. Beds of conglomerate are present where the pebbles have been sufficiently concentrated. Some of these beds are fossiliferous, as will be noted under the description of the several gaps.

The remaining, upper portion of the Shawangunk is similar to the lower part, but almost devoid of pebbles. This was classified as the Otisville member of Swartz and Swartz.[23] The rather coarse, gray sandstone is usually quartzitic and may have a greenish cast. Throughout, the Shawangunk is heavy-bedded and well jointed perpendicular to the stratification. It appears to grade up into the

[23] Swartz, C. K. and Swartz, F. M.: Geol. Soc. Am. Bull. 42, 1931, pp. 621-662.

Bloomsburg by a transition of alternating red and gray beds. But, all above the first red beds is logically placed by Swartz and Swartz in the Bloomsburg, a practice in accord with my own concepts as applied to analogous, Devonian "transitional" beds. The Otisville member continues throughout much of the region north of Northampton County. Simultaneously, the lower portion of the Shawangunk is split up by Swartz and Swartz. West of the Delaware they recognize an upper member which they assign to the Clinton, while the lower part is designated as the eastern extension of the Tuscarora of central Pennsylvania.

Bloomsburg red beds.—(High Falls of New Jersey Geological Survey, Clinton of earlier Pennsylvania geologists). The 1,800 to 1,900 feet of the Bloomsburg "formation" is dominated by comparatively soft, deep-red shale and sandstone. Of this sequence a practically complete section may be seen at the Delaware Water Gap along the railroad and highway up the Pennsylvania side of the river, and a fine sequence is exposed on the Lehigh. Beds of gray or greenish-gray sandstone are not at all rare, and in its lower 150 to 200 feet appear gray sandstone and conglomeratic strata very like those of the Shawangunk. The formation is barren but contains occasional pseudofossils, principally ripple marks and mud cracks.

As far as the present discussion is directly concerned, the higher Silurian formations, that is, those above the Bloomsburg red beds, need not interest us particularly. However, a brief mention of them is not entirely out of place and is introduced below for completeness sake.

Poxono Island formation.—I. C. White described from farther up the Delaware Valley, a formation which he named the Poxono Island shale. At best, it is unsatisfactorily developed in the type locality. Presumably, it continues southwestward into the Water Gap section, and it has been identified with certain, non-red, sandy beds above the Bloomsburg, with which lower formation it is thought to interfinger. The Poxono Island is more truly a sandstone than a shale. The rock is brown or gray-green and weathers to a dark, rusty-brown hue. Exposures are to be seen at Delaware Water Gap village, where these beds are relatively massive and dip north under Cherry Valley. No fossils are known from the Poxono Island, although limy beds have been reported. An estimate of its thickness is unsatisfactory, but is probably of the order of 300 feet or more.

Bossardsville limestone.—The Bossardsville limestone is the highest Silurian recognized in our section, according to present usage, and is the highest formation which shall be mentioned in this account. The Silurian-Devonian boundary has been commonly drawn at the top of

the Bossardsville. Recently agreement has been reached to draw the boundary slightly higher, at the base of the Coeymans limestone. The limestone is probably about 100 feet thick, but its basal contact with the Poxono Island is concealed under Cherry Valley. The rock is a "ribbon" limestone, very similar in lithology to the Tonoloway of central Pennsylvania. This similarity and the abundance of *Leperditia alta* in both are significant criteria for correlating the Bossardsville with the Tonoloway, thereby assigning the former to the highest position in the system by analogy to that occupied by the Tonoloway farther west. The ribbon character of the limestone may be seen in abandoned quarries and cuts in the region north of Kittatinny Mountain.

STRUCTURAL GEOLOGY

The most interesting section structurally is that on the Delaware, although the structures themselves are relatively simple. Folding on the whole is gentle, and dominates. A few gravity faults have been seen, but no overthrusting of consequence is recognized. There is some evidence for believing that a transverse, tear fault occurred at the Delaware Water Gap as will be mentioned presently. Unconformities occur. The most important, however, is that at the base of the Shawangunk separating the Silurian from the Ordovician system. In Northampton County, this is exposed only in Lehigh Gap.

For a section through Delaware Water Gap (see Figure 31, p. 294).

The attitude of the Shawangunk formation in Kittatinny Mountain is mainly monoclinal, dipping northward at angles varying throughout the region. At Wind Gap it lies nearly flat, but at the Delaware and Lehigh rivers, is more steeply up-tilted. The north-dipping beds pass under the Silurian red shales, the Bloomsburg, northward. The Bloomsburg red beds are thrown into a gentle arch on the Delaware, the Kemmererville anticline. This fold is seen to be double-crested on the New Jersey side and is broken at or near the crests by three or four vertical, gravity faults presumably of small throw. The structure is best observed when the leaves are off by one who looks from the Pennsylvania side across the river to the New Jersey shore. The structural relations of the higher Silurian units on the Delaware are obscure, and nothing can be determined directly or precisely anent them except that they maintain a general, relatively gentle north dip and pass beneath the Devonian formations of Godfrey Ridge. It seems probable that the Bossardsville limestone is down-bowed in a broad syncline beneath Cherry Valley, because the lower Devonian beds of Godfrey Ridge dip south.

Westward from the Delaware Valley the Kemmererville anticline noses out in the region of Kemmererville, from which it is named, and probably is not prolonged west of that village. The sequence at the Wind Gap is not so well exposed as at the Delaware, and structures are less clearly discernible. Briefly, the dip is gentler than to the east, and there appears to be no interruption by fold or fault until the top of the Silurian is reached, which is thought to be thrust against beds of early Middle Devonian age in Cherry Ridge.

On the Lehigh, the section is uninterrupted by any important structures. The base is of particular interest. Here the unconformity between the Shawangunk and Martinsburg is exposed clearly. Beds above the Bloomsburg are concealed, so that nothing can be said of their structures.

If one examines the topographic map of the Delaware Water Gap sheet, he will at once notice that the crest of Kittatinny Mountain is offset slightly at the gap. The crest on the New Jersey side appears to have been moved north a few hundred feet relatively in comparison with that of the mountain on the Pennsylvania side. The supposition is that there is a vertical tear fault running up the river valley here, and that the beds on the New Jersey side have been pushed north a short distance relative to those on the Pennsylvania bank. Comparison with the supposed structure and the offsets in Kittatinny Mountain between Delaware Water Gap and the Wind Gap is instructive. The geologic map shows two great S-shaped curvatures in the trace of the mountain crest in this region. Here, the relatively flat-lying Shawangunk has been gently folded in the region of the offsets. Whether further tear faulting has also affected the structure here is doubtful. Talus and timber both contribute to obscure the exposures, but it is not impossible that there has been horizontal movement of the beds relatively northward on the east side of the offsets to those to the west.

COMPARATIVE SECTIONS

Delaware Water Gap section. The section on the Delaware River is readily available for study, as on each side there is a railroad and a road, the excavations along which supplement the natural rock exposures and outcrops for some miles. At Delaware Water Gap the Delaware River has cut through Kittatinny Mountain (also called "Blue," "North," and "First"), a persistent ridge extending east-west for miles across New Jersey and Pennsylvania. The Delaware is but one of several streams which have sawed their courses down through the hard ridge-forming Shawangunk formation, but the gap of the Delaware is considered the most attractive of all, possibly because of the sinuous course of the river here, whereas the Schuylkill,

Lehigh and Susquehanna rivers traverse the mountain more nearly at right angles. The fore (south) slope of Kittatinny Mountain in northeastern Northampton County is precipitous. Cliffs are common along the raw edges of the north-dipping strata, and from their bases sprawl huge talus piles. The north slope is gentler, conforming nearly to the dip of the beds. On the New Jersey side, the surface drops from 1,600 feet at the mountain crest to the valley of Dunnfield Creek, 400 feet above tide at its mouth. On the Pennsylvania side, a 900-foot low point is attained at the head of Poplar Valley. Thence, on both sides, the elevation along the river rises in the low, broad swell of the Kemmererville anticline, already mentioned in the section under Structural Geology. This anticlinal ridge trends parallel to Kittatinny Mountain. Through it the river passes in a curving gorge. Its rock-cut walls are doubtless oversteepened in some places by ice action. Prior to the widening of the highway along the Pennsylvania side of the river, abundant ice-grooving and polishing were preserved in the rock walls about one and one-half miles north of the Gap. At the village of Delaware Water Gap the main valley of the river swings nearly at right angles northeast by east along a non-resistant belt of limestone and shale to Walpack Bend. From here south beyond the Kemmererville anticline the gorge is cut in the comparatively soft Bloomsburg red shale. South of there, the hard, resistant Shawangunk conglomerate and sandstone rise in steep walls in the most spectacular portion of the section. It is this portion which is usually referred to as the gap proper.

For one observing the stratigraphic sequence along the Delaware, it is well to start at a point south of the Gap. A few old slate quarries give a glimpse of the upper part of the Martinsburg. Immediately south of the Gap to the Delaware, Lackawanna & Western Railroad bridge across the river, the great banks of outwash gravel and boulders are a conspicuous sight, and recent highway construction has exposed them splendidly. Entering the gap, a stop at the turn of the road is instructive. Here the great ledges of the Shawangunk rise steeply on opposite sides of the river. By sighting across, it is possible to observe the offset at this point. The exposure of Shawangunk at this turn on the Pennsylvania side includes some of the black, slaty shale common in the formation, and the lithology of the coarser beds may be readily studied. In this part of the formation at the turn of the highway into the Delaware Water Gap on the Pennsylvania side, there were formerly exposed a few black shale interbeds in which eurypterid remains were preserved in a fragmentary state. Here, in 1922, I collected *Hughmilleria shawangunk,* and it may be that this is

the locality from which Clarke and Ruedemann reported the following faunule (quoted from Swartz and Swartz):

Dolichopterus otiseus
Eurypterus maria
Styloneurus cf. *myops*
Hughmilleria shawangunk
Pterygotus cf. *globiceps*

Near this same zone, but on the New Jersey side, Schuchert reported an occurrence of *Arthrophycus allegheniensis,* but I have never had the good fortune to find this fossil on the Pennsylvania side of the river, nor do Swartz and Swartz record it. It should, however, be present, and is common farther west.

Continuing around the curve, the highway nearly follows a strike section for several hundred yards. Dip slope exposures of the Shawangunk are abundant; some show ripple marked surfaces. As we approach the next turn, right (toward the north), the higher, finer, greener beds of the Shawangunk are crossed, and soon after rounding this curve, we observe the first signs of red marking the base of the Bloomsburg formation.

The lower part of the Bloomsburg is peculiarly interesting with its alternation of red and greenish-gray strata. The change of color is usually strikingly abrupt, taking place as it does precisely at the bedding surfaces. Continuing north across the red beds, small local faulting and folding are observable and considerable shearing of the shalier beds as we cross the south limb of the Kemmererville anticline. The Bloomsburg is splendidly exposed all along the highway and on the railroad, particularly in the vicinity of the foundation of the old Kittatinny House, burned a few years ago. A change to more massive, browner beds is observable as the road rises north of the hotel cite, and as one descends again to Delaware Water Gap village, the upper part of the formation is crossed. Beds assigned to the Poxono Island formation are exposed along the west side of the principal street and in a railroad cut at the north end of the platform of Delaware Water Gap station.

Wind Gap section.—The next section west of the Delaware Water Gap that affords a fairly complete view of the sequence of formations is that at Wind Gap. There is little to be seen in the intervening region at Tott and Fox gaps or at the two offsets. Approaching Wind Gap from the south, no satisfactory exposures of the Martinsburg are recognized in the immediate vicinity. The branch line of the Lehigh & New England Railroad which climbs up to the gap from the south-

west traverses the talus slope, and the highway from Wind Gap village ascends the same terrane. However, about a quarter of a mile south of the railroad crossing in the gap, the Shawangunk is well exposed, particularly on the west side of the road. Here the beds lie nearly horizontal, and great blocks have broken off and moved a short distance down grade.

Descending the north slope from the highest point of the gap, the road furnishes a number of cuts in the red beds. These include some rather heavy, dark-red sandstones suggestive of the iron-stone beds of sections farther west. However, neither on the road nor the railroad is a complete section available, and little or nothing can be said of the details of the sequence nor of structures. The Poxono Island formation has not been identified in the Wind Gap section. The Bossardsville limestone, marking the top of the Silurian, is exposed in old quarries on Chestnut Ridge west of Saylorsburg. The white scar of these openings is observable from the highway as it swings in a long arc northeastward beyond Ross Common.

Lehigh Water Gap section.—Between Wind Gap and Lehigh Water Gap, Kittatinny Mountain is nicked by a minor wind gap, Little Gap. A new road-cut exposes the Shawangunk in several places. The strata dip to the south at angles up to 45°. Folding and probable faulting have changed the usual attitude of the beds at this point. The Lehigh Gap section is fully as well exposed as that on the Delaware. It has attracted the interest of geologists for many years. A nearly continuous sequence from the top of the Martinsburg to the Lower Devonian is available along the highway up the east bank of the river from the bridge at Weiders Crossing to Palmerton. Cuts on the Lehigh & New England Railroad give partly supplemental exposures. Along the west side, the Lehigh Valley Railroad affords a good section of cuts, and, after the Lehigh & New England has also crossed over to the west shore, it supplements these with another series of exposures a little higher up the mountain side.

In general the sequence is not much different from that on the Delaware. However, Swartz and Swartz recognize two parts to the Shawangunk. Below, they designate nearly 450 feet as the Tuscarora. This is chiefly heavy-bedded sandstones and conglomerates in which *Arthrophycus alleghenicnsis* occurs. Above these strata they assign nearly 1,000 feet to the Clinton. The beds are somewhat like the underlying strata, but browner and devoid of conglomerate. A minor thrust fault cuts through them about 200 feet above their base. This succession is readily observed on both sides of the river, and is apparently entirely barren.

Thus these sandstone zones may be traced eastward little altered at Little Gap, becoming increasingly massive and conglomeratic farther east, to unite and form the Shawangunk conglomerate at the Delaware Water Gap. The outstanding feature of the region is the change in the character of the sandstones, which become increasingly massive and conglomeratic by the addition of coarser material as they approach the old shoreline on the east, in harmony with the general law of the region.[24]

The still higher beds of the red Bloomsburg formation are partly concealed, and their top is hidden. A total of at least 1,800 feet seems to be present. The Poxono Island and Bossardsville are not known in this section.

Wind Gaps of Kittatinny (Blue) Mountain

Wind gaps are gaps or notches in mountains, cut by streams which were later diverted to other places. They are common features in the Appalachians and elsewhere where adjustments of stream courses to geologic structures have taken place. The name suggests some connection with air currents and at times their origin has been erroneously attributed to the wind. They have received their name because occasionally surface winds are turned or directed by these gaps to such an extent that they are noted by the local residents.

As an illustration of earlier views of the origin of the Wind Gap, the following quotation is given.

Die Wind Kaft, or the Wind Gap, is a depression, notch, or opening in the Blue mountain, which is very abrupt, and extends from the top nearly to the bottom of the mountain. No stream passes through. Various have been the conjectures touching the cause of this notch. The conjecture most prevalent as to the origin of the Kaft is that it was caused by the Delaware River, where, as is supposed, it formed a lake behind the mountain, and may have opened a passage at the notch or gap. Those maintaining this view theorize thus: "That at some time, anterior to the Delaware River having burst its way, where it now runs, there may have been some slight depression at the Wind Gap, and subsequently to the Delaware passing its barrier, vast masses of ice may have choaked up the passage below, where the river again formed a lake, many feet higher than it was in days of yore, and this water may have been discharged, till the ice yielded, and suffered the river once more, and ever since, to pass." This is, however, mere theory.[25]

Wind gaps have usually been named from nearby towns or for families who lived in the vicinity. The prominent one in this region, the one most widely known of all wind gaps in the United States, is seldom called other than the Wind Gap. However, to distinguish it from other less popular ones, geologists have called it the Pen Argyl Wind Gap. The other wind gaps in Kittatinny Mountain in Northampton County from the Lehigh Gap to the Delaware Water Gap are Little Gap, Smith Gap, Fox Gap and Tott Gap. In addition Ver

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[24] Swartz and Swartz: op. cit.
[25] Rupp, op. cit., pp. 25-26.

Steeg[26] has designated two other notches between Smith Gap and the Pen Argyl Wind Gap which he calls wind gaps. With the exception of Little Gap and the Pen Argyl Wind Gap, the writer is inclined to question the origin of all the notches mentioned as due to erosion of once transverse streams. It appears probable that these minor notches are the result of the differential erosion alone.

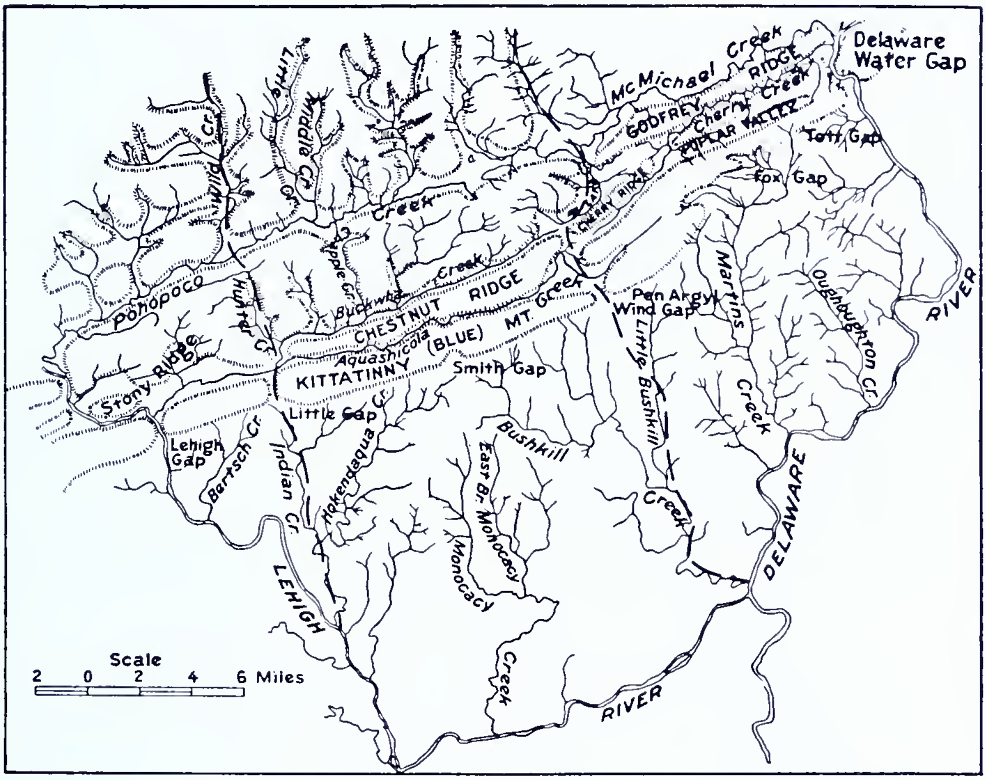

Fig. 29. Original and present drainage of Northampton County Heavy dashed lines indicate the probable courses of streams that cut the notches in Kittatinny (Blue) Mt. but which have since been dismembered by stream piracy.

Conditions are extremely favorable for stream diversion in this portion of the Appalachians and thus for the formation of wind gaps. The ridge of hard resistant rocks forming Kittatinny Mountain is paralleled by a band of soft shales along the northern flank. Tributaries flowing over these soft shales have been able to push their heads backward until they encountered streams crossing the hard rocks of the mountain and cutting very slowly. The processes involved are brought out in the discussion of the two wind gaps named. (Figs. 10, 11.)

[26] Ver Steeg, K., op. cit., Fig. 1.

Little Gap.—An examination of the Mauch Chunk topographic map shows Wild and Hunter creeks north of the mountain flowing south-southeast and in line with Little Gap and on the south side of the mountain with Indian Creek. The alignment is so perfect that there seems little doubt but that the three creeks at one time constituted a single stream that flowed through Little Gap.

The diversion or beheading of this stream was accomplished by the growing headward of Aquashicola Creek which empties into the Lehigh River just above the Lehigh Gap. It was cutting in the red shales, and regardless of the fact that it had less water and few cutting tools it was able to keep pace with the downward cutting of the Lehigh River which was filing its way through the hard rocks of the mountain. On the other hand the Wild-Hunter-Indian Creek with little water was cutting its way slowly through the mountain. When the Aquashicola was extended back to this creek it was at a lower level. Consequently all the upper portion of the Hunter-Indian was captured and led directly into the Lehigh by a shorter course and Little Gap was left unoccupied. The notch or Little Gap is over 300 feet deep. It is clogged with boulders of decomposition so that it has considerably changed since the stream departed. The slopes have decreased but the floor has probably been lowered very little. Indian Creek, now confined entirely to the region south of Kittatinny Mountain, has become merely a tributary of Hokendauqua Creek.

Pen Argyl Wind Gap.—The story of the Pen Argyl Wind Gap is little more than the repetition of the origin of Little Gap. The only difference is that it is not so easy to determine the particular stream that was mainly responsible for the diversion.

A topographic map of the region shows McMichael Creek and Lake Creek north of Kittatinny Mountain in rather close alignment with the Wind Gap and with Bushkill Creek south of the mountain. Lake Creek now shows a reversed course. It is presumed that these three creeks at one time constituted a single stream which flowed through the present streamless gap. In this case tributary streams from both the Lehigh and Delaware rivers were pushing their ways headward in shale until they finally reached the McMichael-Lake-Bushkill Creek. Perhaps a tributary of the Delaware River, the present McMichael Creek below Sciota, was the first stream to effect dismemberment and cut off the upper part of the combined creek.

Cherry Creek, another tributary of the Delaware, and Buckwha and Aquashicola creeks, tributaries of the Lehigh, have also extended their headwaters into the same region and they have probably all been factors in the stream piracy. Ross Common Creek, a tributary of the

Aquashicola which flows past Wind Gap on the north side of the mountain, was the last of the system to be captured and diverted from the old course through the gap.

Bushkill Creek, which now heads south of the Kittatinny Mountain, is of minor importance as the greater part of the original McMichael-Lake-Bushkill Creek lay on the other side of the mountain.

How much change has taken place in the Wind Gap since it was occupied by a stream cannot be determined. It probably has been deepened very little, but erosion has decreased the slopes. The dismembered portions of the old stream have now cut far below the floor of the gap and are still being lowered.

A moot question which has aroused considerable discussion pertains to the correlation of wind gaps with old erosion surfaces (peneplanes). Barrell (1920), Hickok (1933), and Meyerhoff and Olmsted (1934 and 1936) hold to the view that the floors of wind gaps throughout the Appalachians can be correlated with each other in groups and that they are intimately related to the peneplane levels and are thus indicators of cyclic uplifts. Ver Steeg (1930, 1933 and 1935) on the other hand argues strenuously against such relationship. The discussion of this question leads far afield and can not be treated except with consideration of many areas outside Northampton County. Therefore it is regarded as proper to merely state the problem in this volume.

Caves, Sinks and Underground Drainage Systems

In the limestone areas of Northampton County there are many subterranean openings into which surface drainage flows. Even a casual glance at the map shows the paucity of streams in the limestone regions as compared with the slate regions. Over considerable areas between the Monocacy and Bushkill creeks and the Monocacy and Catasauqua creeks the rain water all disappears underground. During dry seasons Monocacy Creek from a short distance south of Bath to Camels Hump contains no water for so long that high weeds grow in the stream bed. At such times the creek takes a more direct course underground and reappears as a large spring on the right bank of the creek north of Pine Top.

Sink holes are common features in the fields of the limestone area. Into these sinks the farmers dump glacial field stones and refuse of all kinds. Some report the enlargement of the sinks in spite of repeated efforts to fill them. One also hears of farm animals falling into underground cavities.

So numerous are these caverns that until recently nearly all the residents of the towns built on limestone disposed of their house

sewerage by dumping it into "wells" that extended down to some opening. Occasionally stoppage of these channels has necessitated the sinking of new holes but in most cases this method of sewage disposal has been entirely satisfactory. Bethlehem and Easton in recent years have constructed sewers, but by no means all the homes have changed their old method by connecting with them.

In Lehigh County close to the Northampton County line a hole bored for drainage purposes has a strong downward draft of air during the winter and an equally strong outward current of cold air in summer. In a quarry in East Allentown there are small openings where similar conditions exist.

All of these occurrences furnish evidence of the cavernous character of the limestones of the county. There are several places where openings either natural or artificial permit access to fairly large caves. These have long been known and at times exploited. Lost Cave, generally called the Hellertown Cave, is the most important one.

These caves have been described in the volume on Pennsylvania Caves of this Survey.[27] The descriptions which follow are quoted from that report.

BETHLEHEM

It is reported that a cave under the Sun Inn once gave access to the creek and later was used for sewage disposal, but the entrance to this cave has long since been filled and nothing can be learned of it now.

CARPENTER CAVE

By E. R. Barnsley

This tiny, pretty cave on the old Carpenter farm owned by the late Dr. Edward Hart of Lafayette College, is situated in Northampton County, a quarter of a mile from the Delaware River and about a mile northwest of the little village of Raubsville. One must be athletic, and not too large to explore this cave, because, first the entrance hole, which is less than three feet across, drops six feet vertically, and, secondly, the crevices are very narrow and often times so blocked as to require wriggling along the floor to get past.

When the writer visited this cave in the Tomstown limestone, he went in over 100 feet, but the latter half was achieved more by climbing and squirming than it was by walking. The main crevice is sinuous and slightly descending from the entrance, and there are several minor offshoots that undoubtedly could be gotten into if considerable effort was expended.

As a whole, this cave has neither the beauty nor size of some of the other caves of the region, but it does contain some beautiful dripstone having a clean snow-white translucency. Also there are some small rimstone pools on the floor, and one dripstone column nine inches through and two feet high.

COLD AIR CAVE

In the west bank of Delaware River above Slateford and close to the east entrance to Delaware Water Gap, a signboard calls attention to Cold Air cave, which, with the lunch stand that conceals it, belongs to Mrs. Myrtle Williams of Slateford.

The mountain side here is covered with a talus or floe of large blocks from the Shawangunk sandstone that outcrops above. A broad flat slab of this sandstone resting on a large chunky block at the foot of the talus roofs

[27] Stone, R. W., Pennsylvania caves: Pa. Top. and Geol. Survey, 2d ed., 143 pp., 1932.

over a space only a few feet square. At the back of this space the voids between other blocks are large enough for a man to crawl into them a few feet.

When visited November 6, 1931, a thermometer in one of these cavities registered 38° F. Cold air coming out on a warm morning makes fog. This cold air, which received its low temperature from the frosts of the previous winter, is stored by Nature in the voids of the rock floe. Cold air tends to settle, and, being held in the floe by the cover of soil and vegetation, it moves slowly down hill through the spaces between the blocks and emerges noticeably in summer at this opening.

A storage room for soft drinks has been built in front of this small hole to conserve the cold air for cooling purposes.

INDIAN CAVE

In the west bluff of Delaware River four and a half miles north of the bridge at Easton, at the head of Indian rift and foot of Sandts eddy, is the so-called Indian cave. A small eating stand at this point operated by Elmer L. Yeager bears a sign with the name of the cave.

Indian cave is in Beekmantown limestone about thirty feet above Route 611, on land formerly owned by Adam Iop. The entrance is wide and head-high so one can walk in, then stooping a bit through a short passage and turning left, one may walk upright to about ninety feet from the entrance. Here a hole in the floor leads to a slightly lower room, in the bottom of which is a depression filled with trash. This is said to be the blocked entrance to a still lower passage.

The floor of the cave is partly buried in clay. The site and suitability of the cave suggest that it may have been used by Indians for shelter and watching the river trail. The view from the entrance is extensive because of the bend in the river.

The cave shows traces of dripstone, but the roof is everywhere within arm's reach and all calcite formation has been removed.

At the back of the first room is an iron gate. Its presence is explained by the fact that about sixty years ago Adam Iop in quarrying stone for his lime kiln broke into the upper and outer room. He took out a license to sell beer and other drinks, charged ten cents admission, and perhaps stored his bottled goods in the cave, for the temperature is said to be about 48° F. the year around.

A second and smaller opening just north of the main entrance leads into a room about ten by twelve feet in size, from which goes a low three-foot passage parallel to the face of the ledge for about forty feet. At this distance it is too low or choked with stone for further progress.

The limestone beds seem to lie nearly flat and jointing is more closely spaced at the main opening than elsewhere in the exposed ledge.

LOST CAVE

In 1883 men quarrying limestone about half a mile east of Hellertown discovered a cave in the Tomstown limestone. Because of its location close beside a good road only four miles from Lehigh University at Bethlehem, it has for many years been visited by students, for educational purposes. Many parties and fraternity initiations have been held here.

In the spring of 1930 this plot of ground was purchased by E. C. Gilman and formally opened to the public May 24, 1930 with the name Lost Cave. The property is owned by the Lost Cave Corporation, E. C. Gilman, president. Good walks have been placed, electric light installed, passageways enlarged, and picnic grounds with parking space provided. By removing earth and loose rock from passageways and by enlarging crevices, rooms never before seen by man have been opened. These new rooms are hung with stalactites and crystals of cave onyx sparkle in the flowstone that covers the walls.

The passages are irregular, winding, with gentle grades and two short flights of concrete stairs. The length of the cave in a straight line from entrance to rear wall is 330 feet but the windings and side gallery make the route traversed about 900 feet.

The highest ceiling is about seventy feet and the cave at its widest place is about sixty feet.

In the Lake Room the floor is covered with five to six feet of water. This room is about forty feet long, fifteen feet high, and fifteen feet wide, and has many stalagmites. The Ball Room is so called because years ago it contained a small dance platform. A small underground stream may be seen for about seventy feet in a newly opened room.

The temperature of the water and cave is 50°. In general the beds strike N. 50° E. and dip N.W. 38°.

REDINGTON CAVE

This cave, in the Tomstown limestone, is situated at the far end of the abandoned limestone quarries of the Bethlehem Mines Corporation at Redington which is along the Lehigh River about five miles east of Bethlehem.

Part of the cave has been quarried away, and now the entrance is through a very narrow passage and down over a steep slippery talus slope of fallen blocks into a large room that is roughly circular in floor plan and measures about fifty feet in diameter. The height is about forty feet. One long passageway extends up to the left for 250 feet in a straight line. The floor rises rapidly and the width decreases until finally there is just enough room for a small person to squeeze between three blocks and enter a low vaulted room. Exploration is possible from the opposite side of this little room, but it was too dangerous to attempt to explore without the use of a rope as descent must be made over an almost vertical slope.

Parallel to this channel and a few yards northeast of it is another crevice but this is only two feet wide and progress is soon blocked. A light will show that it continues on for a hundred feet or more.

This cave contains much formation and even rivals several which are commercially exploited. The roof throughout practically its entire extent is covered with pencil-like stalactites, and in places it fairly bristles with beautiful slender and hollow forms some of which are a foot long.

Another interesting type of deposit is the arborescent calcite that is here better developed than at any of the other caves visited. These curious little aggregates of calcite crystals sometimes grow to be an inch high, and their overlapping branches and stubby base make one think of a winter landscape of sleet-encrusted shrubs.

In the ceiling near the back and at the right side of the large room is a small crevice along a bedding plane and up about fifteen feet from the floor is a layer of travertine that evidently at one time rested on clay filling but subsequently the clay has been removed and this calcareous floor remains in testimony of the fact that water running in the rocks is as fickle as it is upon the surface.

STRATIGRAPHY AND PETROGRAPHY OF THE PRE-CAMBRIAN ROCKS AND PALEOZOIC IGNEOUS ROCKS

By Donald M. Fraser

General Statement

The pre-Cambrian rocks of Northampton County occupy a belt five to six miles wide which extends across the southeastern part of the county. The formations that make up the pre-Cambrian series include the Franklin formation composed of the Franklin limestone and graphite-quartz schist members, Moravian Heights formation, Pochuck gneiss, and Byram gneiss with associated pegmatites. In-folded and in-faulted Paleozoic quartzite and limestone occur as irregular northeast-southwest bands within the pre-Cambrian area.

There is no good evidence of the age relations of the first three of these formations, all of which have been tentatively assigned to the Archean[27] and Algonkian. It is possible that the Franklin formation corresponds to the Grenville,[28] the Moravian Heights to a sedimentary formation of the Huronian, and the Pochuck gneiss to the volcanics of the Huronian.

The Byram granite gneiss and associated pegmatites are intrusive into the earlier formations. It is likely that the period of invasion of granitic materials occupied a considerable time in the geologic past, but because of the general lack of prominent metamorphism in the Byram its emplacement probably represents a later rather than an earlier Proterozoic introduction of granitic material.

These tentative age assignments have been made without definite evidence and therefore must be regarded as somewhat unsatisfactory but at least they represent a reasonable sequence of formation.

Graphitic quartz schists and graphitic Franklin limestone are often found in the same area; likewise Pochuck gneiss is often associated with one or both of the graphite-bearing formations, and with the Moravian Heights formation. In only one place, however, are the relations between any two of the three earlier formations exposed. This is in the eastern end of Chestnut Hill, north of Easton, where the Pochuck is in contact with the Moravian Heights. This locality is discussed later under the description of the Pochuck gneiss.

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* On the geologic map the area on south slope of Morgan Hill designated as Pochuck should be Byram. Small band of Franklin north of Chestnut Hill should be shorter and narrower.

[27] The time scale or classification followed in this report is that used by the Pennsylvania Topographic and Geologic Survey. Ashley, G. H., A Syllabus of Pennsylvania Geology and Mineral Resources: Pa. Topog. and Geol. Survey Bull. G1, Pl. 1, 1931.

[28] The U. S. Geological Survey considers the Grenville as Huronian in age. Wilmarth, M. G., The Geologic Time Classification of the U. S. Geological Survey compared with other classifications: U. S. Geological Survey Bull. 769, Plate I, 1925.

The Byram granite gneiss has intruded the earlier formations and in a number of places has silicified the Franklin limestone and intimately injected and assimilated not only the Franklin limestone but the graphitic schist and the Pochuck gneiss as well. Pegmatitic facies of the Byram cutting the earlier formations and also the normal Byram commonly show indistinct border relations to the other rocks.

REVIEW OF PAST WORK

Early workers[29] in the pre-Cambrian of eastern Pennsylvania and New Jersey recognized the presence of a basic gneiss showing definite streaking and banding, an acid gneiss having less noticeable streaking, a metamorphosed limestone, and foliated gneiss and mica schist. The basic gneiss has been described by numerous workers as having been derived from a basic diorite or a gabbro. The acid gneiss has been identified at different times as a granite gneiss,[30] and as a quartz monzonite.[31] A third gneiss in the New Jersey district, of igneous origin and having a mineralogic composition intermediate between the Pochuck and the Byram was named "Losee Pond" by Wolff and Brooks.[32] Spencer[33] later shortened the name to "Losee." This formation has not been distinguished in the Northampton County pre-Cambrian belt, and is considered to be one of the assimilation products formed by the invasion of the Pochuck by the Byram. Wherry[34] recognized and described the Moravian Heights formation as a quartz-sillimanite-sericite rock containing varying amounts of injected Byram material. The major units of the area, therefore, have been recognized for many years and the general relations fairly well understood. It has seemed desirable, therefore, to retain the names used in previous work and to give credit to Doctors Wherry and Miller for the naming of the Moravian Heights formation. This name has not previously appeared in print but has been used by these men and their co-workers over a period of 20 years. In the continuation of this pre-Cambrian

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[29] Britton, N. L., An. Rpt. State Geol., New Jersey for the year 1886, Pub. 1887.
Wolff, J. E. and Brooks, A. H., The Age of the Franklin White Limestone of Sussex Co., N. J.: Eighteenth An. Rpt. U. S. G. S., pt. II, p. 410, 1898.
Spencer, A. C., Kümmel, H. B., Wolff, J. E., Salisbury, R. D., and Palache, Charles, U. S. Geol. Survey, Geol. Atlas. Franklin Furnace folio (No. 161), 1908.
Bayley, W. S., Kümmel, H. B., and Salisbury, R. D., U. S. Geol. Survey Geol. Atlas. Raritan folio (No. 191), 1914.
Peck, F. B., Preliminary Report on the Talc and Serpentine of Northampton County and the Portland Cement Materials of the Lehigh District: Pennsylvania Topog. and Geol. Survey, Report 5, 1911.

[30] Spencer, A. C. and others, op. cit.
Jonas, Anna I., Pre-Cambrian and Triassic Diabase in Eastern Pennsylvania: Bull. Am. Mus. of Nat. Hist., vol. 37, pp. 173-181, 1917.

[31] Bascom, F., Wherry, E. T., Stose, G. W., and Jonas, A. I., Geology and Mineral Resources of the Quakertown-Doylestown District, Pennsylvania and New Jersey: U. S. Geol. Surv. Bull. 828, p. 13, 1931.

[32] Wolff, J. E. and Brooks, A. H., op. cit., p. 439.

[33] Spencer, A. C., Kümmel, H. B., Wolff, J. E., Salisbury, R. D., and Palache, Charles, op. cit., p. 5.

[34] Wherry, E. T., Pre-Cambrian Sedimentary Rocks in the Highlands of Eastern Pennsylvania: Geol. Soc. America Bull., vol. 29, pp. 375-392, 1918.

belt to the southwest, both in the vicinity of Boyertown and Reading, Stose and Jonas have contributed considerable to the knowledge of the various formations. A recent publication[35] by these workers on the area extending southwestward from a point south of Allentown, expresses views which the writer of this paper definitely opposes, but which have been of great value in stimulating interest in the structure of the pre-Cambrian belt. It is noted that Bayley has contributed considerable toward the knowledge of the pre-Cambrian of New Jersey, and Stose and Jonas to the pre-Cambrian of the area to the southwest; Miller and Wherry have been the most active workers in the past in the region under discussion in this publication.

ACKNOWLEDGMENTS

The writer expresses his deep appreciation to the senior author for encouraging the study of the pre-Cambrian formations. In addition, a map of the pre-Cambrian area within the Allentown quadrangle made by Wherry and Miller was of great value in re-mapping that part of Northampton County. The writer has used freely the information presented by Wherry in a manuscript on the pre-Cambrian of the Highland belt of Eastern Pennsylvania. Numerous discussions with B. L. Miller, E. T. Wherry, G. H. Ashley, B. Willard, R. D. Butler and J. W. Peoples have assisted materially in the interpretation of the formational relationships of the area.

A National Research Council grant for thin sections is gratefully acknowledged.

FORMATION DESCRIPTION

GENERAL STATEMENT

The interpretation of the mapping of the pre-Cambrian rocks of Northampton County will be facilitated by an understanding of the assumptions made at the time of the mapping of the area. None of the pre-Cambrian formations show clean-cut contacts with any of the other formations older than the Hardyston. The Franklin formation and the Moravian Heights formation, both of which are interpreted as having been formed from primary sediments, do not give evidence of their respective ages and, except for one exposure in the eastern end of Chestnut Hill where the Moravian Heights is in contact with the Pochuck, their structural relations to the Pochuck gneiss are not exposed. The Byram granitic material, which in places shows an indistinct gneissic structure, everywhere shows intrusive relations to the above-mentioned three formations. The general situation through-

[35] Stose, G. W. and Jonas, A. I., Highlands near Reading, Pennsylvania; An Erosional Remnant of a Great Overthrust Sheet: Geol. Soc. Am. Bull., vol. 46 (1935), pp. 757-758.

out the area is that the earlier three formations are very intimately invaded by granitic material. Pegmatitic material in part probably accompanying the Byram invasion and in part as late as post Hardyston, has also injected earlier formations.

On the map (Plate I) formation contacts are represented by solid lines rather than dots or dashes. These solid lines do not, however, indicate a clean-cut, readily recognized and accurately determined contact plane. They indicate that in so far as the author of the map was able to judge, the materials on either side of a zone having the approximate location of the line on the map were of two types. Commonly, a decision had to be reached on the difference between the invading Byram gneiss and one or the other of the older formations containing abundant introduced Byram material.

The fairly consistent northeast-southwest strike of the formations has resulted in a similar alignment of the remnants of the injected materials.

Within the larger areas shown as either Pochuck gneiss or Byram granitic gneiss, one may expect to find small injections or inclusions of the other material, but within any area indicated as one or the other of these formations, the expectation is for a preponderance of that material.

Franklin Formation

Distribution.—This formation occurs along the Delaware River in Chestnut Hill at the eastern end of the pre-Cambrian belt and extends southwestward across Bushkill Creek toward the western end of Chestnut Hill. A smaller area is found near the western edge of the county along the west bank of Monocacy Creek where it cuts the western end of Pine Top.

Lithologic characteristics.—The more extensive member of the formation is a coarse-grained graphite-bearing limestone. Where unaltered by igneous intrusions it is a dense, white crystalline carbonate rock with scattered flakes of graphite and fewer grains of magnetite and silicate minerals appearing locally. In the Chestnut Hill area, this formation has been invaded by pegmatitic material, the emanations from which have altered the limestone to a serpentine mass. The intimate invasion of the limestone by silica solutions has resulted in numerous new silicate minerals. These are listed under the chapter dealing with the minerals of the county.

The graphitic quartz schist associated with the Franklin limestone in other areas in the pre-Cambrian belt is not present in Chestnut Hill but is fairly abundant in the fields just west of the Franklin limestone area along Monocacy Creek. Here it is composed chiefly of

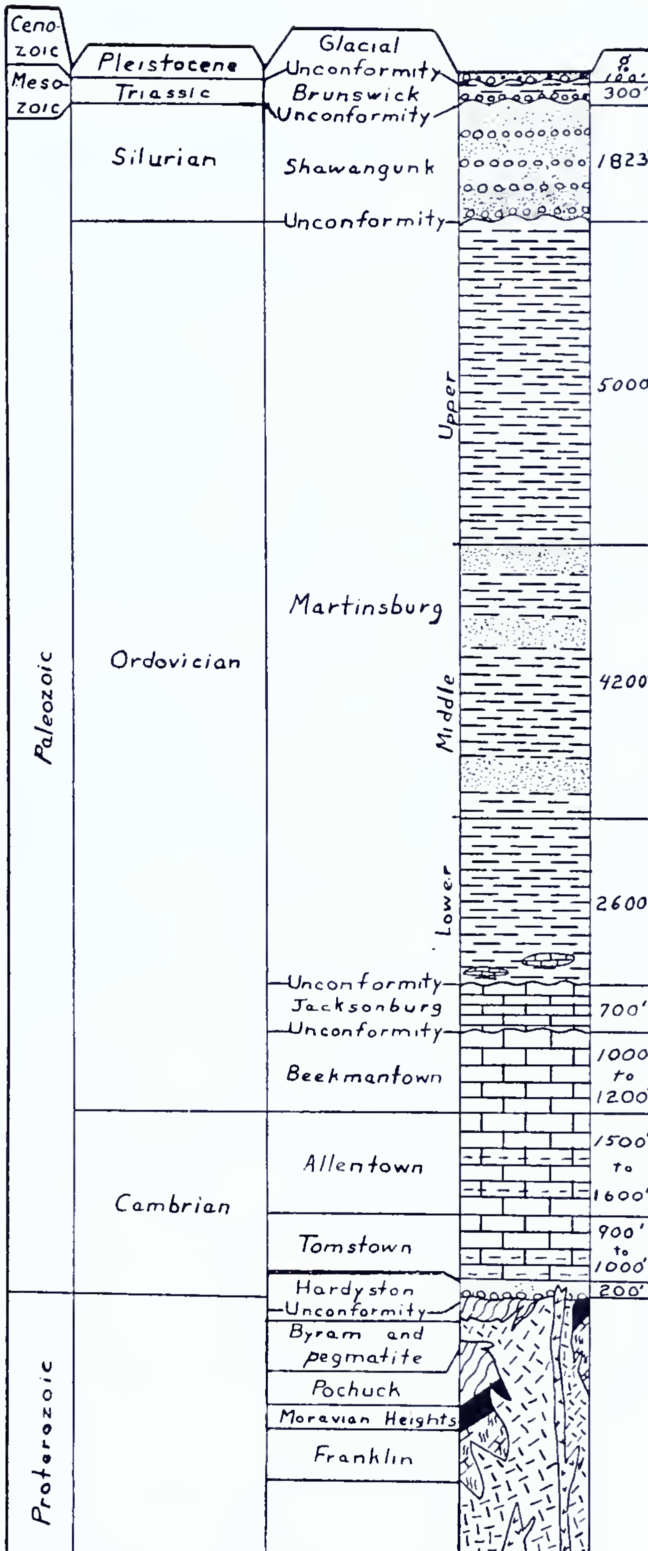


Figure 30. Geologic column of Northampton County.

quartz grains with which are associated smaller amounts of feldspar and graphite scales. In the field, this rock commonly has a smoky quartz appearance due to disseminated graphite particles, and is essentially a silicified arkosic sandstone in appearance. Some specimens are massive and have a sub-conchoidal fracture similar to that of quartzite and fine-grained diabase; other specimens with more feldspar and less quartz have a rude gneissic structure. All, however, are characterized by the presence of graphite.

Thickness.—The thickness of the Franklin limestone member of the Franklin formation is unknown. Exposures of serpentinized limestone in Chestnut Hill quarry show the material at present to be between 50 and 100 feet thick. There is little indication of bedding planes, and these figures are merely a statement of the vertical depth of workings in the serpentinized area. Wherever supposed bedding or gneissic flow planes are observed in the limestone, within the pre-Cambrian belt of eastern Pennsylvania, these planes show considerable distortion, and one is unable to estimate the thickness of the formation measured across the bedding.

No good exposures of the graphite-quartz schist are found in the district but on the basis of the extent of the outcrop, it may be assumed to be a few tens of feet thick. In all probability it was originally several tens of feet in thickness and must have been of considerable areal extent because it is found scattered throughout an area of many tens of square miles in the pre-Cambrian belt of eastern Pennsylvania.

Name and correlation.—The Franklin formation in this area has been tentatively correlated with the Franklin limestone of New Jersey, which was named by Spencer,[36] in the area of Franklin, New Jersey. The true sedimentary origin of the Franklin formation was determined as early as 1898 by Wolff and Brooks.[37] These authors credit the earliest mention of the formation to William Maclure in 1809, who described a "large-grain marble on the edge of the Formation, near Sparta." The formation was studied and discussed by a number of workers following Wolff and Brooks, and in 1908 Spencer and others described the "Franklin limestone" in detail. This is apparently the first use of the term Franklin to designate the formation which had previously been discussed as the "white limestone" in distinction with the "blue limestone" of Paleozoic age found in the vicinity.

In Northampton County the associated graphitic quartz schist has been included with the limestone to comprise the Franklin formation. This has been done because of their consistent association in the field and the prevalence of graphite in both members, probably indicating

[36] Spencer, A. C. and others: op. cit
[37] Wolff, J. E. and Brooks, A. H.: op. cit.

their mutual sedimentary origin. The Franklin formation is considered to be Archean in age, roughly equivalent to the Grenville limestone of the Adirondack area.

Stratigraphic and structural relations.—Without having definite evidence for doing so, the Franklin formation is thought to represent the oldest or certainly one of the oldest formations in the district. It occurs in only small isolated areas, and with the exception of the Moravian Heights formation which also has a small areal distribution, the Franklin formation is present in much smaller areas than the other pre-Cambrian rocks. There is little evidence to indicate the relative age of the Franklin and Moravian Heights formations and Pochuck gneiss, and they therefore must be considered as representing the earliest series of rocks in the district. The sequence of formation which has been assumed places the Franklin formation first, Moravian Heights second, and the Pochuck gneiss third. Only rarely is it possible to show the nature of the contact between any two of these three formations, and their relative positions in the field have not made it possible to determine the super-position of one above the other.

Petrography and petrology.—The microscope reveals that the Franklin formation is composed of carbonate material of considerable variation in texture. All phases are holocrystalline and the dominant structure is massive. More rarely a rude planar structure is observed, often considerably folded. This may be due to the retention of original bedding but it is more likely the result of layers of silicates and graphitic material which have been developed during the metamorphism of the original limestone. Many specimens show grains whose twinning lamellae and cleavages have been distorted. A rock of this type may, of course, have suffered several periods of recrystallization and (or) crushing and only show evidence of the more recent processes. Spencer[38] and Miller[39] give chemical analyses of the Franklin limestone, as shown on next page.

The Chestnut Hill area.—The largest single area of the Franklin limestone is exposed on the south side of Chestnut Hill along the northern edge of Easton. Quarry operations in this district have exposed the formation which is now largely a serpentine mass and in some places have cut into irregular pegmatitic masses of quartz and feldspar where these bodies have invaded the limestone. The solutions accompanying this stage of the igneous activity in the area have permeated the entire mass of the older rock and have, by the processes of silication and silicification, changed the carbonate material to cal-

[38] Spencer, A. C. and others: op cit., p. 3.
[39] Miller, B. L., Limestones of Pennsylvania: Pennsylvania Topog. & Geol. Survey, 4th ser., Bull. M 20, p. 589, 1934.

Chemical composition of Franklin limestone

	1	2	3	4	5	6	7	8	9	10
CaO	53.11	52.39	51.06	53.53	51.96	28.31	29.68	51.80	48.40	54.79
MgO	.94	.84	3.02	1.73	2.92	18.04	20.07	1.37	5.25	—
FeO	—	—	—	—	—	—	—	—	—	—
Fe_2O_3	.37	.55 }	.80	.50	.20	1.20	3.50	.15	.90	.90
Al_2O_3	.21	.69 }								
Na_2O } K_2O	—	—	—	—	—	Trace	—	—	.50	.16
CO_2	—	—	43.44	43.97	44.03	42.08	45.51	42.23	43.80	43.06
Graphite } insoluble	—	—	1.40	.55	.20	9.50	.50	1.70	.27	.75
Water	—	—	—	—	—	—	—	1.80	.20	.15
So_3	—	—	—	—	—	—	—	—	—	—
SiO_2	2.08	2.78	—	—	—	—	—	—	—	—
$CaCO_3$	94.74	93.46	—	—	—	—	—	—	—	—
$MgCO_3$	1.96	1.75	—	—	—	—	—	—	—	—
Fe	.26	.39	—	—	—	—	—	—	—	—
	—	—	99.72	100.28	99.31	99.13	99.26	99.05	99.32	99.81

Nos. 1 and 2. B. L. Miller, op. cit. 2½ miles north of Bethlehem, on the west side of Monocacy Creek.

Nos. 3, 4 and 5 from Ann. Rept. New Jersey State Geologist, 1871, p. 44. 3. From lands of J. B. Titman, west of Sparta. 4. Ordinary white limestone burned at Franklin furnace. 5. From West Vernon (locality not specified). Represents an average specimen.

Nos. 6, 7, 8, 9 and 10 from Geology of New Jersey, 1868, pp. 403, 404. 6. From lands of J. B. Titman, west of Sparta. 7. From a drift tunnel northeast of the New Jersey Zinc Company's mine at Sterling Hill, near Ogdensburg. 8. From Geo. W. Rude's quarry (1868) near Hardystonville, now worked by Windsor Lime Company. 9 and 10. From a quarry on the farm of Peter J. Brown (1868), Vernon Township.

cium magnesium silicates with associated quartz. Some of the original carbonate material was, of course, recrystallized without silication so that at the time following the invasion, although secondary silicates dominated, some calcite and dolomite were also present. Analyses I and II below of the serpentinized limestone given by Peck[39] show the expectable increase in silica over that found in the less altered limestone, analyses of which are shown in the above table.

The serpentine samples were collected in the Fox Quarry which lies above and just west of the large quarry now operated along the Delaware River road north of Easton. This quarry at road level was earlier called Sherrer quarry but is now known as Williams quarry.

Serpentine Rock from Fox Quarry

	I	II
SiO_2	46.80	42.94
Al_2O_3, Fe_2O_3	3.14	3.76
CaO	.82	.67
MgO	38.70	40.58
H_2O	10.64	12.00
	100.10	99.95

[39] Peck, F. B., The Talc Deposits of Phillipsburg, N. J. and Easton, Pa., also Pennsylvania Topog. and Geol. Survey, Rept. 5, p. 11, 1911. An. Rpt. State Geol. New Jersey for the year 1904, P. III, p. 174, 1905.

Peck[40] describes the alteration of the limestone-dolomite beds to talc and serpentine as follows:

> Wherever these pegmatites are found cutting the crystalline limestones and dolomite, or wherever they are found anywhere in their immediate neighborhood, the latter become utterly changed in character from their original condition. The contact effect of these granitic masses on the limestone-dolomite beds aided at least in building up in the rock one or more silicates of lime and magnesia, such as tremolite, pyroxene or phlogopite. Locally these silicates entirely replaced the original carbonates, but all intergradations can be found from nearly pure limestone or dolomite, containing but small amounts of the silicates, to rocks consisting wholly, it may be, of either pure white tremolite or white pyroxene, or an aggregation of phlogopite mica scales, or mixtures of these different mineral species.
>
> Then followed the subsequent alteration of these silicates of lime and magnesia to either serpentine or talc. In this alteration the tremendous forces which folded, squeezed, stretched and faulted the rocks into their present condition, together with the hydrating and leaching power of ever present water, were the principal factors.

The serpentine minerals have apparently developed as an alteration, in many cases at least, of other previous silicate minerals. The silicates may have formed from the limestone during the earlier part of the period of pegmatitic activity or at the time of some still earlier igneous invasion. From the physical nature of the serpentine as observed at present, it seems rather obvious that some of it was formed by the serpentinization of micaceous minerals. Another type of serpentine likely was formed from diopside which has been found in a partially serpentinized form. In addition dense serpentine, possessing thin layers of a darker type of serpentine, is thought to represent the completely altered diopside because the former material was found both in close association with unaltered diopside and in what is apparently a gradation occurrence into the latter.

The sequence of events leading to the present mineralogical composition observed in the serpentinized mass is thought by the writer to be somewhat as follows: (1) The original metamorphism of the area containing the pre-Cambrian limestone caused the recrystallization of this material into a coarsely crystalline carbonate rock and a concentration of the carbonaceous material in the form of graphite scales. This action may have been long continued or the same processes may have been repeated at intervals through the pre-pegmatitic period. It is also likely that earlier granitic invasions in the general area may have resulted in some silication of the original material. The most dominant change, however, resulted as follows: (2) Pegmatitic invasion with the formation of numerous silicate minerals including pyroxenes and micas. (3) The hydrothermal attack of the silicated mass by solutions which may represent the later phases of the peg-

[40] Peck, F. B., 1911: op. cit., p. 23.

matitic invasion. This produced the serpentinization observed at present. (4) The introduction, by the pegmatites, of uranium-bearing minerals during or subsequent to the serpentinization. (5) Movement in the mass which has produced talc and tremolite zones along planes of slipping. (6) The formation of secondary uranium-bearing minerals.

C. K. Cabeen has recently investigated the serpentine deposit and has suggested that it may be due, not so much to the introduction of pegmatites and accompanying solutions, as to the action of emanations from the Byram granite at a time preceding the pegmatitic invasion. He states in an unpublished manuscript:

1. The granite dikes, though showing strain effects, are not badly crushed or contorted as would be the case if they had suffered as much dynamic metamorphism as the serpentine has undergone.

2. If the change had been accomplished by the granite dikes, metamorphism should be most intense at the contact of the dikes and the serpentine and should become progressively less. This is not the case.

3. Many of the later granites have very abundant black tourmaline, indicating the presence of the active mineralizers. These would have had an active effect on the surrounding limestone and such calcium borosilicates as danburite and axinite should be present in the serpentine but are not found.

4. The later granites are more sodic than potassic and do not constitute as likely an agent for the formation of phlogopite as would an orthoclase granite.

5. The process by which a dolomite would be converted to serpentine consists of intense dynamic metamorphism involving crushing, kneading and shearing accompanied by the presence of solutions bearing silica and water at high temperatures and pressures. This requires the complete passing of the solutions freely through the mass and the complete molecular reorganization of the material. The intrusion of dikes would leave areas untouched if only moderate conditions prevailed. The change from dolomite to serpentine had been accomplished before the granites intruded for the contact metamorphic effect of granite on dolomite would be the production of vesuvianite, of which only one piece was found, chondrodite and lime garnet in quantity which are not found.

Although the Franklin formation is thought to consist dominantly of the Franklin limestone and the quartz graphite schist previously mentioned, it may also include clastic sediments of a somewhat more argillaceous type. In the outcrops of pink granite occurring between the river and the highway just east of Williams' serpentine quarry, one finds an occasional block of what may be interpreted as having originally been shale or sandy shale associated with limestone. At present this material has been largely altered to sericite, chlorite and epidote. It is fine-grained, the average grain size being on the order of a tenth of a millimeter, and although some of the silica particles may be the original material, most of the mass has been altered. It does not have the characteristics of the Moravian Heights formation, which was apparently an arenaceous rock with a smaller amount of argillaceous material. No sillimanite needles were observed in these

blocks found in the red granite which appear to be xenolithic blocks caught up by the invading igneous mass. It is not entirely clear why they should not have developed a more schistose structure if they are of equivalent age with the Franklin limestone. This structure might well have been preserved in the supposed xenolithic blocks but does not appear. This material, therefore, is somewhat anomalous in its occurrence and does not lend itself to easy classification with any of the other sedimentary formations. Professor Cabeen has informed the writer that similar material occurs in a small area in Marble Mountain on the New Jersey side of the Delaware approximately opposite the occurrence of the serpentine mass in Pennsylvania. Peck[41] briefly described a series of beds from this locality as follows:

> Above this limestone series, though separated somewhat from it by diorite gneiss, occurs the other unusual series of beds (2d), which consists of talcose rocks of light color, passing into grayish-green chloritic rocks more or less slaty in character, containing pebbly beds, jaspery beds of impure hematite, or beds of very pure hematite, in rapid alternation. On the summit of Marble Mountain these beds have a thickness of 50 to 75 feet, and years ago were prospected quite extensively for iron ore, but with no paying results.

Further studies of the New Jersey area may throw additional light on the nature and origin of this material.

Monocacy Creek area.—The Franklin limestone is also exposed in the old quarry on the west side of Monocacy Creek where it cuts the western end of Pine Top. At this place the limestone varies from a fine granular to a coarse crystalline marble-like material. All types contain disseminated flakes of graphite which increase in size in proximity to pegmatitic intrusions. Silicification and silication of the limestone also occur in the neighborhood of the pegmatites. Along the south side of the old quarry the limestone layers are contorted and show small folds overturned to the north.

In the field to the west and northwest one finds blocks of the quartz graphite member of the Franklin formation. Here also are blocks of the Pochuck gneiss which for the most part show invading Byram material. One large block roughly ten to twelve inches on each side and four to six inches thick was found in the field just west of the quarry. This block was made up of coarsely crystalline Franklin limestone and a silicate rock which resembled somewhat silicified Pochuck. The specimen is important because it may give a clue to the age relations of the Franklin and Pochuck formations. It is described below so that the reader may have the information presented by this material and draw his own conclusions. The writer feels that there

[41] Peck, F. B., op. cit., p. 183.

is no conclusive proof for the age of the silicate material and has therefore been unable to convince himself of the age relations.

The specimen as found shows angular fragments of a silicate rock (composed of diopside, quartz, feldspar, carbonate and titanite) cemented together by the crystalline limestone. Graphite scales are present in the silicate rock, which condition has been interpreted to mean that the limestone was invaded and partly assimilated by magmatic material. The limestone contains disseminated grains of pyroxene which might also have been introduced at the time of the magmatic invasion.

Following the introduction of magmatic material, the solidified rock must have been crushed and the limestone then forced to flow into the resulting fractures.

The invading igneous material may have been the Pochuck or the Byram. If the former, the absence of iron oxide in the altered rock and its abundance in the typical Pochuck must be accounted for. On the other hand, the numerous titanite grains are a more expectable product from the Pochuck than from the Byram. The Byram, by introducing silica that would combine with the lime and magnesia of the limestone, could have formed the diopside but the typical Byram, found just across the Monocacy in a rather less contaminated form than usual, would not be expected to carry so much titania.

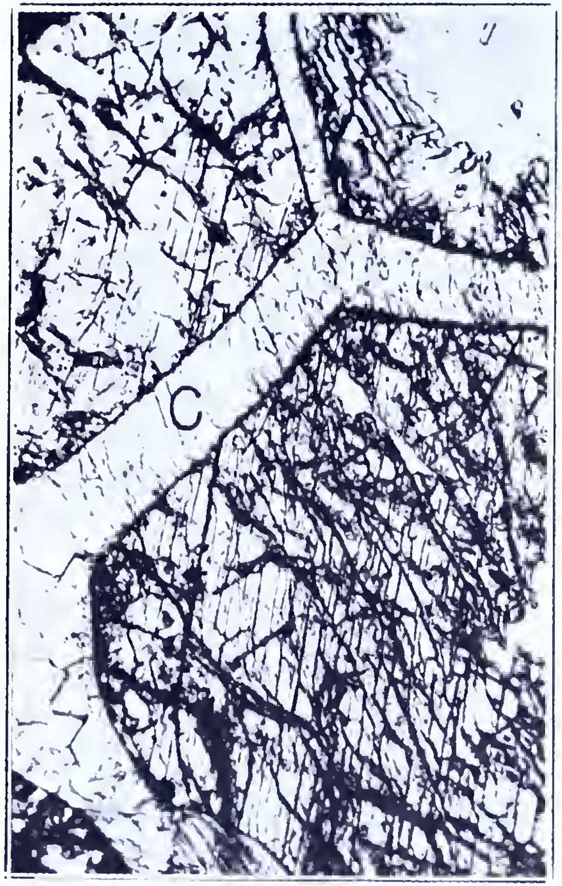
The close proximity of Pochuck material to the limestone is offset by the presence of pegmatitic material. There could, therefore, have been an invasion of acid or (and) basic igneous material insofar as field relations are concerned, either or both of which may have contributed to the present structural and mineralogical relationships, which are interesting even though not completely understood.

Moravian Heights Formation

Distribution.—Materials of the type of the Moravian Heights formation occur on the south slope of Chestnut Hill north of Easton and in larger masses in the Fairview School ridge south of Easton. This formation occurs in other areas scattered through the pre-Cambrian area which extends toward Reading. The two larger of these in Northampton County are about four miles east and six miles southeast of Bethlehem.

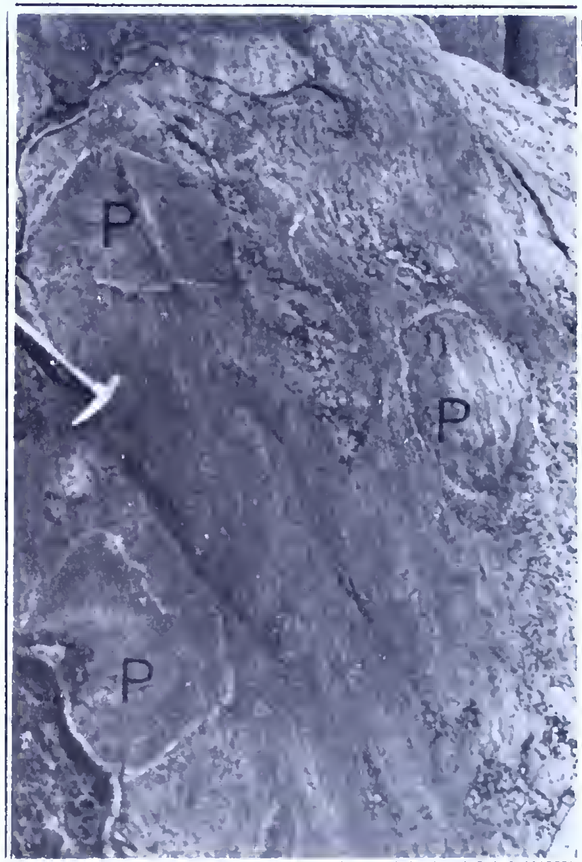
Lithologic characteristics.—In the field the formation is recognized by blocks of light gray to light greenish material which contains parallel streaks of a serpentine-like mineral. These streaks are composed of sericite and sillimanite. The blocks in some places are completely bounded by clean cut joint surfaces and commonly show two or more

PLATE 6.



A. Veins of calcite (c) separate the pyroxene crystals. x40

B. Deformed calcite crystals (c) adjacent to a pyroxene crystal. x40 Pyroxene crystals developed in the limestone and later deformation caused flowage and recrystallization of the limestone.



C. Byram granite gneiss with irregular partially assimilated blocks of Pochuck gneiss (P).

PHOTOMICROGRAPHS OF PYROXENE CRYSTALS IN FRANKLIN LIMESTONE

smooth plane surfaces resulting from jointing. It appears therefore that the formation has failed, under stress conditions, along more or less orderly sets of joints, which has resulted more consistently in joint blocks than has been the case in the Byram or Pochuck formations.

Thickness.—The Moravian Heights formation has been greatly thickened by the injection of igneous material. It is impossible to estimate the thickness of the formation as it now exists or as it existed in its original state. The broadcast area of the Moravian Heights is in the eastern extension of Morgan Hill along the Delaware River. This area on the map, however, cannot be interpreted to mean a very great volume of sillimanite. The mapping has been done on the assumption that wherever streaks of sericite and sillimanitic material are at all common the rock is the Moravian Heights formation. In many places an assumption of this sort has resulted in the mapping of Moravian Heights where by far the greatest volume of material is the injected granitic minerals. In general, therefore, we may interpret the areas of Moravian Heights as being areas in which Moravian Heights material has been injected by a later granitic magma. The maximum width across the strike of such areas is on the order of three-quarters of a mile but this tells us nothing of the actual thickness of the original sedimentary material.

Name and correlation.—This formation, which occurs as a quartz-sericite-sillimanite schist, has been described in previous publications[42] but has not been given a name in print. Drs. B. L. Miller and E. T. Wherry and other workers who have had a part in mapping the geology of the Bethlehem district have long used the term Moravian Heights formation to designate this rock. The name Moravian Heights therefore is published in this bulletin for the first time although it has been in use for many years. The Moravian Heights formation in the Chestnut Hill occurrence is a plot of irregular width occurring adjacent to the Franklin limestone. No contacts between the two formations are observed and both have been considerably injected and altered by the invasions of Byram granitic material. No evidence is presented in the county that gives the relative age of the Moravian Heights to the Franklin formation and only the one exposure in the eastern end of Chestnut Hill shows a contact of the former with the Pochuck gneiss. The relationship there is discussed under the Pochuck. Because both have been formed from sedimentary materials and show a comparable degree of metamorphism, the

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[42] Miller, B. L., Topographic and Geologic Atlas of Pennsylvania, 206, Allentown Quadrangle, p. 144, 1925.
Wherry, E. T., Pre-Cambrian Sedimentary Rocks in the Highlands of Eastern Pennsylvania: Geol. Soc. America Bull., vol. 29, pp. 379-385, 1118.

Moravian Heights and the Franklin are considered to be of approximately the same age. It should be added that both have suffered dynamic metamorphic changes and later injection. In the absence of satisfactory evidence for the age of the Moravian Heights, it has been tentatively assigned to the Huronian.

Structural relations.—The Moravian Heights is commonly found as blocks on the slopes of the hills, and in only a few places are definite outcrops of the formation seen. Where such outcrops occur, the streaking or banding, which has been determined by injection along the planes of schistosity, is usually measurable. Contacts of this formation with other pre-Cambrian rocks, except the injection relations of the Byram, are rare. An exposure in the eastern end of Chestnut Hill shows a contact of the Moravian Heights (merely remnants of the quartz-sillimanite-sericite schist in more abundant injected Byram granitic material) and the Pochuck. The former occurs as a ten-foot member in a series of Pochuck beds dipping to the northwest at an angle of fifty-nine degrees. Irregular pegmatitic masses cut the other formations and obscure the nature of the contact except at the southeastern side of the exposure where the parallelism of Moravian Heights and Pochuck layers is evident. This exposure is discussed further under the Pochuck gneiss.

Petrography and petrology.—In thin-section the Moravian Heights formation invariably shows linear to tabular schistosity. This structural appearance is due both to orientation of sillimanite needles and a stretching of quartz grains of the original material, and to invasion of the formation along parallel planes by a later granite magma. Most types of the Moravian Heights are very rich in quartz. The sillimanite needles occur as inclusions in quartz grains, as aggregates of smaller prisms extending across the boundaries of several quartz grains, and as larger single prismatic or acicular crystals that give a streaked appearance to the rock. The quartz grains are commonly stretched and in some cases considerably elongated so that they may be six or eight times as long as they are wide. It appears that the material had been subjected to dynamic metamorphism which resulted in the recrystallization of quartz to produce greatly elongated grains, and of the original argillaceous material to form the present sillimanite. That some of the stress conditions of this period or later were not entirely relieved by recrystallization is indicated by the abundance of strain shadows observed in the quartz grains.

Wherry[43] has described this rock and has discussed its mineralogy with a table of the minerals found, and their percentages, as given below.

	1	2	3	4
Quartz	55.4	52.6	49.7	50
Sericite	5.9	40.0	15.7	20
Sillimanite	35.1	6.8	24.3	25
Accessories	——	——	——	5
Feldspar (altered)	——	0.4	5.0	—
Biotite	1.6	0.1	——	—
Ilmenite	1.95	0.05	——	—
Pyrite (and limonite)	——	——	5.2	—
Zircon	0.05	0.05	0.05	—
Apatite	——	——	0.05	—
	100.00	100.00	100.00	100

1. One mile west of Seidersville (206).
2. Two miles southeast of Freemansburg (217).
3. East edge of Allentown quadrangle, one mile south of Lehigh River (6396). (Two miles east of Redington.)
4. The rounded-off average of 1, 2, and 3.

Wherry discussed the origin of this material and on the basis of mineralogical and structural evidence suggested its derivation from an original sedimentary type. He concluded that the presence of sillimanite indicated a noteworthy alumina content of the original sediment and thought that very likely the material was originally an argillaceous sandstone. The present writer[44] has discussed the sericitization of certain types of the Moravian Heights and has found that the areas of sericite encroach upon and cut across the stretched and strained quartz crystals shown in the thin sections. This would indicate that the alteration had occurred definitely later than the stress responsible for the oriented crystals. In all probability, we may assume that the original sedimentary material, which was likely a shaly sandstone as interpreted by Wherry, was completely metamorphosed into a quartz-sillimanite schist with, very likely, accompanying mica, before the introduction of the solutions responsible for the sericitization.

In its present form the Moravian Heights commonly shows only scattered remnants of the original sillimanite needles. In some places the thin sections indicate the former presence of occasional sillimanite prisms, only by the ocurrence of small square areas now occupied by sericite scales and fibres. Such square cross-sections of sillimanite partially altered to sericite are found in other thin sections and indicate the true nature of these bodies in the rock.

With the invasion of a granitic magma, the Moravian Heights formation was acted upon by at least two major processes: (1) The

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[43] Wherry, E. T., Pre-Cambrian Sedimentary Rocks in the Highlands of Eastern Pennsylvania: Geol. Soc. America Bull., vol. 29, pp. 375-392, 1918.
[44] Fraser, D. M., Sericitization in the Pennsylvania Highlands: Proc. Penn. Acad. Sci., vol. X, pp. 66-71, 1936.

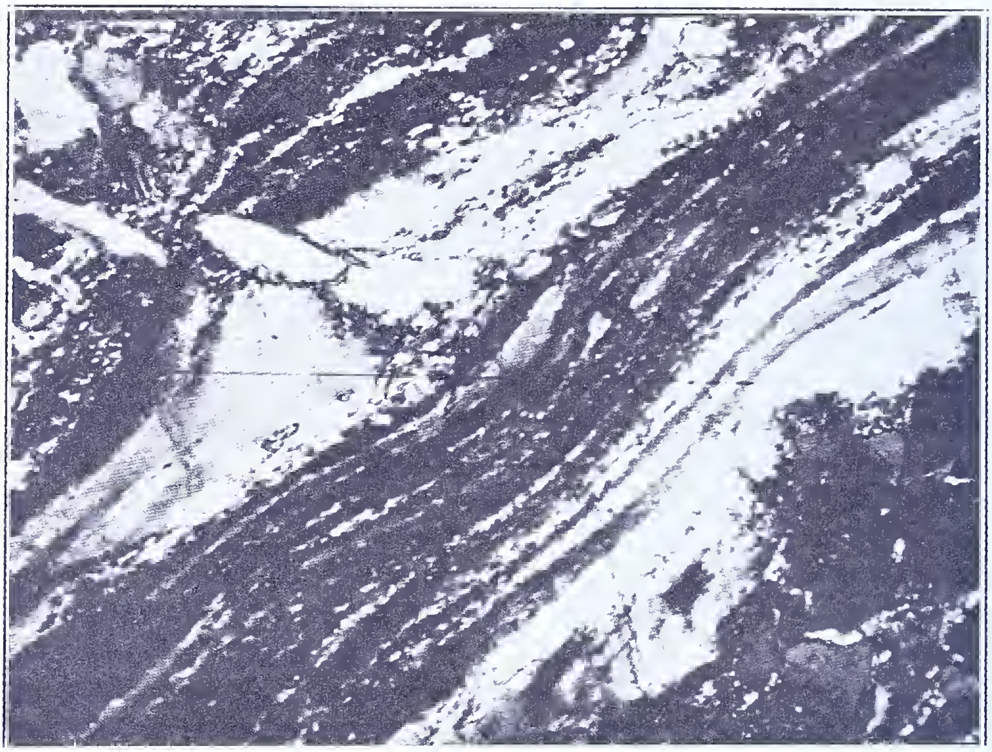
formation was intimately injected by granitic materials which parted the original schistic and gneissic planes and introduced granite layers between them. This type of material is that which most commonly occurs in those districts indicated as Moravian Heights. In some of these specimens the volume of introduced granitic material is dominant over that of the primary material. (2) At a later period, hydrothermal solutions attacked the Moravian Heights formation and altered the rock in part to sericite. The breaking down of the original minerals resulted in the sericitization of the sillimanite first, with the partial sericitization of quartz, following or accompanying this other change. As observed at present, therefore, the Moravian Heights rocks are considerably recrystallized and hydrothermally changed. What was originally an argillaceous sandstone is now partially sericitized layers and lenses of material often largely dominated by the invading granite mass.

Local details.—An interesting situation exists between the Moravian Heights and Byram materials along the southeastern slope of Morgan Hill. In this vicinity a shear zone extending northeast and southwest is several hundred feet wide. Within this belt the rocks, whether pegmatitic, granitic or schistic, have been extensively granulated and numerous cataclastic structures developed. In thin section the materials range from mylonitic bands made up of grains of quartz and feldspar only a few microns in diameter to layers of crushed quartz and feldspar in which the fragments are fractions of an inch in diameter. These fractions show abundant strain shadows. It is interesting that the sericitization of sheared pegmatitic and granitic material has resulted in a rock type that in the hand specimen closely resembles the injected and sericitized Moravian Heights formation. The mapping of the Moravian Heights belt in this area shows the quartz-sericite-sillimanite rock ending a short distance from the base of the slope delineated by a northeast-southwest fault. No material that was positively identified as Moravian Heights type could be found at the base of the slope although a superficial examination of much of the sheared material at this place would lead one to conclude the presence of the sillimanite-bearing rock. This particular sheared zone is the most highly developed in the pre-Cambrian belt of Northampton County.

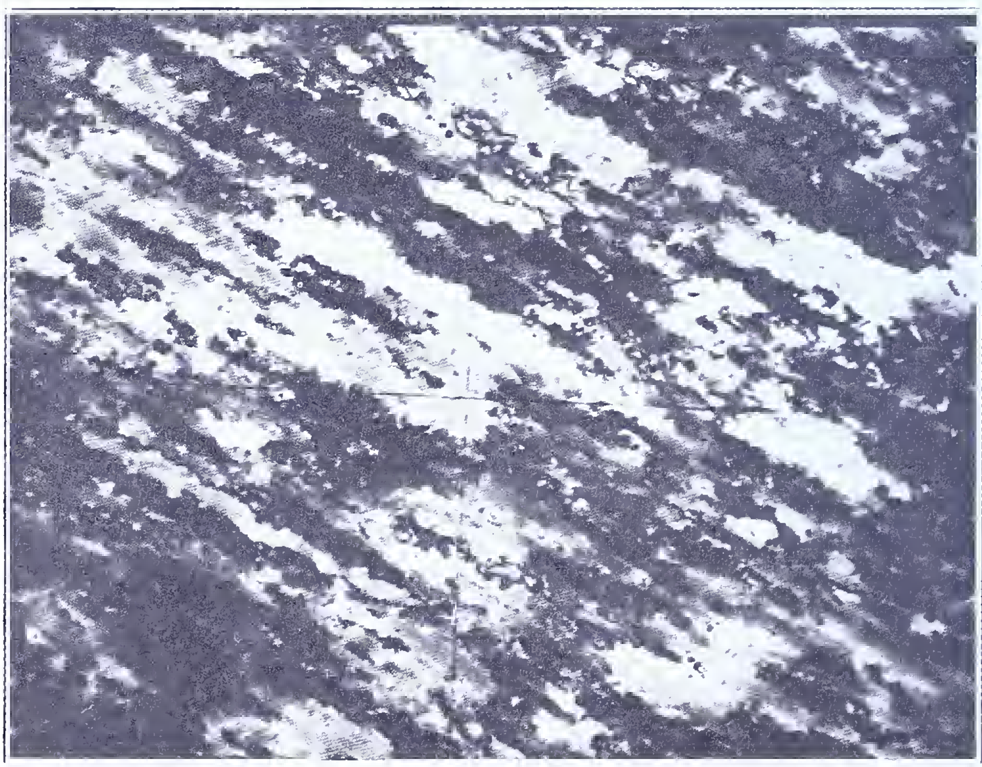
Pochuck Gneiss

Distribution.—The basic Pochuck gneiss, which is essentially a hornblende-andesine rock, is most abundant near the middle part of the pre-Cambrian belt extending across the southern part of North-

PLATE 7.



A. Sheared pegmatitic Byram from east end of Morgan Hill. x50



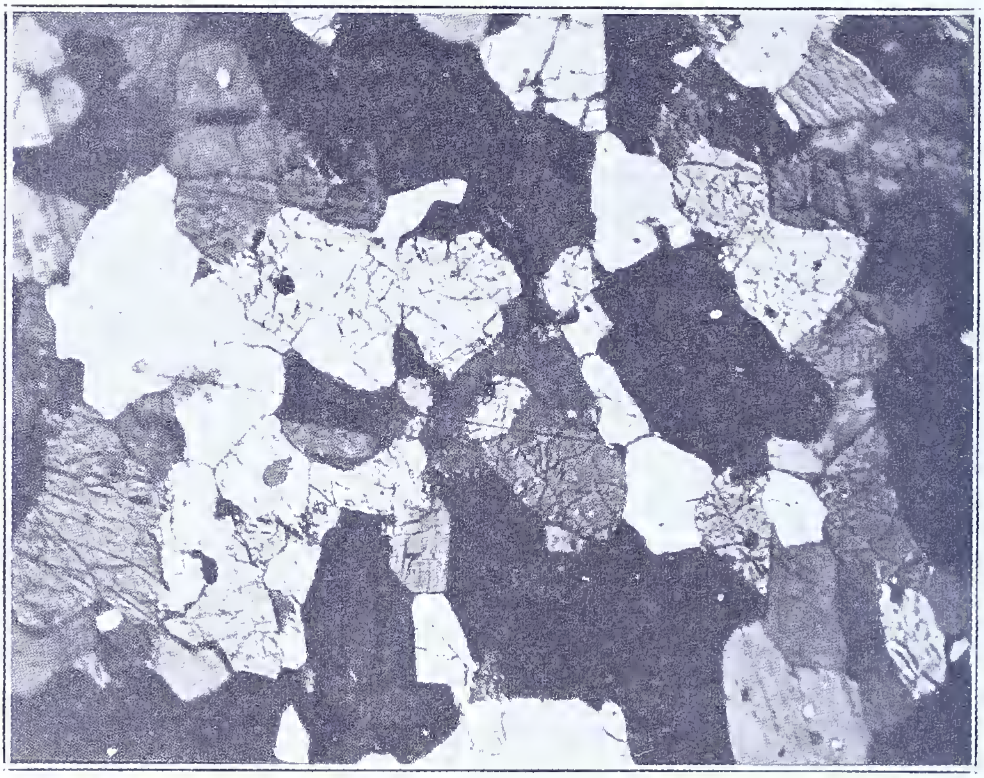
B. Mylonite from road cut opposite Fairview School on southwestward extension of Morgan Hill ridge. x50

Photomicrographs of highly sheared rocks from Morgan Hill area.

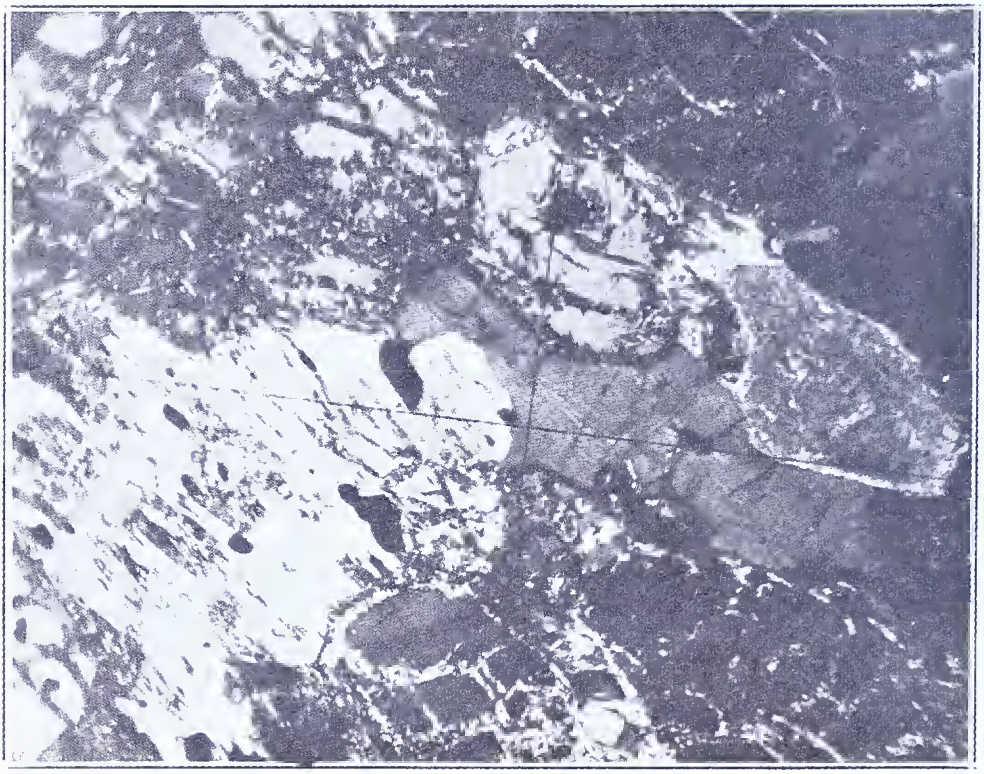
PLATE 8.

A. Pochuck gneiss showing rude parallel structure.

B. Pochuck gneiss invaded by Byram and contorted. North side of Steelys Hill.



A. Fresh Pochuck. Lighter grains, andesine, laboradorite; darker grains, hornblende. x60



B. Pochuck partially altered to chlorite, epidote and sericite. x150
Photomicrographs of Pochuck gneiss.

ampton County. In this district, an area of six to eight square miles is occupied chiefly by the Pochuck material. Smaller areas occur in Morgan Hill, in the hills along the southeastern county line and in the South Mountain area south of Bethlehem. Although Hexenkopf Hill and neighboring peaks are composed of Pochuck material this formation does not consistently make high points.

Lithologic characteristics.—A gneissic structure is usually present in the Pochuck gneiss. This is caused by the orientation of hornblende or biotite grains parallel to a plane or a direction, and in part by the grouping of these minerals into parallel streaks or irregular bands. Where the formation has been invaded by the Byram granitic material, the gneissic appearance may be accentuated by the alternate light and dark layers that result from this intrusion. In the field the Pochuck commonly appears as a dark green or greenish-black rock which may or may not show structural directions or weakness. If the rock has suffered silicification, as much of the material has, the tendency to break along the gneissic directions is often completely lacking.

Although the Pochuck is generally composed of hornblende and andesine, it shows many variations in composition. Biotite-andesine facies appear as well as hornblende-pyroxene-andesine facies. They grade into each other and both grade from their purer form into types in which Byram granitic material dominates.

Thickness.—The Pochuck gneiss is of such irregular occurrence and shows so few contact relations with other formations that its thickness is impossible to determine. If it is the metamorphosed equivalent of a former diorite or diorite gabbro, the subject of thickness would be omitted; if it has been formed from lava flows we might expect its original thickness to be possible of determination in some way, but no evidence along this line has been observed.

Name and correlation.—This formation was given its name by Wolff and Brooks[45] from Pochuck Mountain in New Jersey. They describe it as follows:

> The gneissic outlier of Pochuck Mountain is represented by two bands of rock. The eastern band, which adjoins the valley and forms the eastern slope of Pochuck Mountain, we have called the Pochuck gneiss. This gneiss is about half a mile in width, and has been traced from near Hamburg to the northern edge of the area mapped. The prevalent rock type is a finely foliated gneiss, rich in biotite and hornblende, and often grading into a micaschist. With this mica-hornblende gneiss are often associated bands of amphibolite gneiss. The latter rock consists essentially of plagioclase, green hornblende, and quartz, with some biotite, and is probably a squeezed dioritic rock.

[45] Wolff, J. E. and Brooks, A H., op. cit., p 440.

Earlier reports of basic rocks appeared in the Annual Reports of the State of New Jersey. One of these[46] describing a Bedded Diorite presents Kemp's observations on the alteration of augite to hornblende.

Bedded Diorite.—The rock Diorite occurs generally as an eruptive, but it is also found in the stratified condition. It consists essentially of the minerals Plagioclase, Feldspar and Hornblende, though others are commonly present in small quantities. Field No. 621, from near the Pennsylvania railroad bridge, on the shore of the Delaware, at Trenton, is of this type. Mr. Kemp studied this rock, and found it to consist of Plagioclase, Hornblende, Magnetite and Biotite; as matters of petrographical interest he states that the Hornblende is peculiar, the edges of the crystals being uniformly blue or green, and show optical properties different from the inner portions, which are normal Hornblende. This is interbedded with Gneissic rocks, having strike N. 35° E., and dip 80° SE.

Field No. 415, from the western slope of the Pimple hills, in Sussex County, is similar, and probably to be classed with the Bedded Diorites, though more study of it is needed to determine this certainly. Mr. Kemp remarks: "It consists of Plagioclase, Hornblende, Augite and Magnetite with traces of Titanium. The intermingling of Hornblende and Augite is exceedingly interesting from a petrographical standpoint. The one is probably an alteration or development of the other. The same cracks continue through the two minerals, and they project into each other, and border on each other, with no sharp crystalline distinction. Yet the Hornblende is deep green or brown and pleochroic, and Augite well-nigh colorless, and showing no traces of pleochroism. This development, or possible alteration, of the two minerals is a very prominent question among mineralogists." Other specimens of stratified Hornblendic rocks may prove to be of this nature, but the above are the only ones which have been accurately studied.

In New Jersey the Pochuck as described by Spencer[47] and others is used "to include all the gneisses occurring in the Highlands region that contain hornblende, pyroxene or mica as principal mineral constituents. Some of these rocks are probably of sedimentary origin, and others may be altered igneous rocks, but in general they are so completely metamorphosed that their original nature cannot be ascertained." In the Raritan quadrangle, Bayley states:

The rocks included in the Pochuck gneiss are all dark colored and generally black, on account of their large content of pyroxene, hornblende, and biotite. They have a wide range in mineralogic composition and are composed mainly of oligoclase, orthoclase, diopside, hornblende, hypersthene, biotite, magnetite, and quartz, in various proportions. Some specimens contain all these minerals, but as a rule two or more are absent. Magnetite is the most constant component, though oligoclase and hornblende, and green pyroxene are generally present.

It will be seen that the materials considered as Pochuck by Wolff and Brooks included not only the dark colored gneissic or schistose material but also foliated gneiss and mica schist. The later workers tended to confine the name Pochuck to the dark colored gneissic or schistic material. The present writer uses the name Pochuck for

[46] Britton, N. L., op. cit., pp. 104-105.
[47] Spencer, A. C., and others, op. cit., p. 4.

the dark colored gneisses containing hornblende, pyroxene and (or) biotite as dark constituents and oligoclase-andesine or andesine-labradorite as the more common plagioclase minerals. Quartz and magnetite are commonly present, and titanite, chlorite, epidote and other minerals appearing as accessory or secondary minerals are not infrequent.

Origin.—Spencer and others thought the Pochuck was derived from both sedimentary and igneous rocks. Bayley[48] concludes as follows:

> It therefore seems probable that the black gneisses which have been included under the term Pochuck gneiss should properly be divided into two groups of different age and possibly of different origin, the first group comprising gneisses, possibly of sedimentary origin, older than the Byram and Losee gneisses, and the second group comprising dark gneisses of igneous origin contemporaneous with the Byram and Losee gneisses.

Wherry[49] in discussing the Pochuck concluded, in 1918, that the evidence pointed to "the ultimate sedimentary origin of the bulk of these rocks." In discussing the basic rocks of the Allentown and Easton quadrangles Wherry[50] concluded as follows:

> . . . a few areas of dark gneisses occur in which the petrographic characters place the igneous origin of the rocks above question, and these have been separately mapped, under the name gabbro, the term Pochuck being thus limited to rocks of either probably sedimentary or entirely undetermined origin.

More recently Wherry[51] has considered the basic material to be of igneous origin and has considered the above mentioned gabbro to be merely a basic phase of a rock which is characteristically more feldspathic but still in the diorite gabbro division of rocks.

The present writer considers the Pochuck as described in this report to be entirely of igneous origin. Furthermore, he wonders if the original form of this material may not have been andesitic and basaltic lava flows. The composition of the present material, excluding the great volume of introduced silica, which of course raises the total silica content, is such that the material might have been originally of flow origin. The considerable linear extent of this formation, although certainly not excluding the diorite or diorite gabbro origin, would conform very well to the flow hypothesis.

If it could be shown that the Pochuck gneiss has been derived by the metamorphism of flow rocks of intermediate and basic character, it might be thought to be equivalent in age to one of the pre-Cambrian

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[48] Bayley, W. S., Kümmel, H. B., and Salisbury, R. D., op. cit., p. 63.
[49] Wherry, E. T., op. cit., p. 390.
[50] Wherry, E. T., unpublished manuscript.
[51] Wherry, E. T., personal communication.

lava series of the northern Great Lakes area. It may be suggested that the Pochuck be correlated with lavas of the Huronian.

In answer to the suggestion that the Pochuck has been derived from the lavas of Keewanawan age, the close association with the Franklin and Moravian Heights formations and the more definite metamorphism of the Pochuck than the Byram granitic material have been the deciding factors in arriving at a tentative conclusion that the Pochuck, if of lava flow origin, is more likely to be correlated with the Huronian than the Keewanawan.

The occurrence of uniformly dipping Pochuck and Moravian Heights bands in the eastern end of Chestnut Hill may be explained more easily by assuming the original flow or (and) sill origin of the Pochuck than by suggesting the invasion of a diorite or gabbro. It is of course true, even though no cross-cutting intrusive relations now exist, that such evidence might expectably be destroyed through subsequent metamorphism. The very parallelism of the highly injected Moravian Heights and Pochuck layers may be largely due to alignment during the invasion of the Byram.

This discussion is obviously quite unsatisfactory and is merely the expression of the writer's views at the present time based upon field work and studies of thin sections. These views are, therefore, open to criticism and will very likely be altered as more information is brought to light by future studies.

Stratigraphic and structural relations.—Little field evidence is available to indicate the relative stratigraphic position of the Pochuck gneiss with either the Franklin formation or the Moravian Heights. It has been tentatively assumed that the latter two are older than the Pochuck.

In no place does one find the contact relation between the Pochuck and Franklin formation, and only at the eastern end of Chestnut Hill is the relation to the Moravian Heights indicated. They may occur in adjacent areas but, except as noted, they are not exposed together in stream valley, road cut, or quarry.

In the Chestnut Hill exposure about ten feet of Moravian Heights beds (abundantly injected and partially assimilated by Byram) are in contact with Pochuck beds. The Moravian Heights formation conformably overlies the Pochuck gneiss and both formations strike N. 50° E. and dip northwest at an angle of 59°. The present physical superposition of the Moravian Heights gives no indication of their relative periods of origin because all the rocks of the pre-Cambrian have been extensively disturbed. Inferences may be drawn, however, regarding the material from which the Pochuck gneiss has been derived. This subject is considered under the origin of the Pochuck.

Pegmatitic material overlies the Moravian Heights beds, above which the Pochuck, invaded by Byram and pegmatite, again appears. It might be suggested that here we have an isoclinal fold with the Moravian Heights forming the core but these beds are truncated in such a manner by the pegmatite that their possible former continuation in a parallel limb to the northwest has been lost. It is not possible to determine, therefore, whether the Pochuck is older, younger or interbedded with the Moravian Heights.

The relations with the Byram granitic material are very definite. The Pochuck is the older rock and has been invaded and assimilated in varying degrees by the younger formation. This invasion occurred at a depth in the earth's crust sufficient to result in a plastic state of the Pochuck at the time of the entrance of the Byram. Contorted schlieren of the Pochuck material are found in the Byram near the contact with definite Pochuck gneiss. All stages are found from 100 percent Pochuck material composed of hornblende and andesine to 100 percent Byram composed of quartz, microcline, microperthite, and orthoclase. In this range there are, of course, types which show the entrance of small amounts of quartz and orthoclase into the Pochuck, types in which the rock is a typical mixed material with about equal amounts of invading and invaded minerals, and types in which scattered grains of hornblende and saussuritized andesine in Byram material are the evidence of incorporated Pochuck. The structural relations, therefore, of the Pochuck and the Byram are those chiefly of the invasion and assimilation of the former by the latter; this invasion being extensive and intimate.

Petrography and petrology.—In thin section the Pochuck gneiss is found to be more variable than one would expect from an examination of the hand specimens in the field. Megascopically, the material is characteristically a speckled granulose type of rock possessing a rude structural alignment. The minerals observed in the hand specimen are recognized as hornblende and plagioclase feldspar. In addition, certain phases contain biotite with or without hornblende and (or) pyroxene. Some phases contain rather abundant hornblende and pyroxene crystals. Under the microscope the plagioclase varies from oligoclase to labradorite in composition. The accessory minerals are apatite, magnetite, titanite, zircon and occasional other grains of much less abundance. The material commonly alters by the development of hornblende from pyroxene and the breaking down of plagioclase to produce saussurite. Epidotization is common where silicification of the Pochuck is prominent.

Analysis of the Pochuck gneiss[52]

W. T. Schaller, Analyst

SiO_2	43.98	K_2O	1.10
Al_2O_3	12.01	H_2O	.29
Fe_2O_3	6.60	H_2O+	1.04
Fe_2O	12.20	TiO_2	2.25
MgO	5.46	CO_2	.18
CaO	11.99	P_2O_5	.28
Na_2O	2.93	MnO	.05

The introduction of a large volume of silica into the pre-Cambrian formations is an interesting feature of these rocks. It is at times accompanied by microcline and (or) albite and apparently has been derived from a granitic magmatic source. In certain localities the introduced silica runs as high as 15 percent and has resulted in the development of quartzitic types of rocks from the normal Pochuck and other associated formations. In the case of the Pochuck gneiss, the granitization or silicification, as the case may be, has been accomplished by the encroachment of quartz and microcline and (or) albite upon plagioclase dominantly, but also upon hornblende, pyroxene or biotite in many instances. These encroachment areas are irregular in shape and a single one may attack two or more grains of the original minerals of the rock. The resultant structure resembles the interlocking outline of a jigsaw puzzle. With a more active type of invading material, the original minerals of the Pochuck may be completely absorbed by the introduced magmatic material. This results in an increase in the lime content of the then liquid mass, over that of the introduced magma, which, upon later crystallization, produces a plagioclase less calcic than that found in the normal Pochuck but more calcic than would have resulted from the crystallization of the invading material before the assimilation of the basic rock. This process was recognized by Wherry[53], who described the basic gneiss many years ago. More recently the writer[54] has described assimilation relationships of the Byram to the Pochuck as exhibited by the rocks of the area south of Macungie, Pa. One may expect to find every stage of assimilation ranging from small amounts of quartz and alkali feldspar introduced into the Pochuck to rocks composed of quartz, oligoclase, microcline and hornblende, which represent the solidification of the granitic magma plus the assimilated Pochuck gneiss.

Local details.—The injection relations of the Byram into the Pochuck are shown in the steep northern slope of the hills one mile south-

[52] Pardee Mine, Franklin Furnace Quadrangle: U. S. Geol. Survey Geol. Atlas, Raritan folio, field edition, p. 61, 1914.
[53] Wherry, E. T., op. cit.
[54] Fraser, D. M., Igneous assimilation near Macungie, Pennsylvania: Proc. Penn. Acad. Sci., vol. IX, pp. 34-38, 1935.

west of Redington. This district, mapped as Byram gneiss in the lower northern slopes with bands of Pochuck occurring toward the crest of the ridge and extending down the southern slopes, shows the involved nature of the two formations. The difficulty of deciding on the contact plane is readily appreciated from examination of outcrops in this area. The Byram occurs as layers of varying thickness interfingering with bands of Pochuck gneiss. These bands of Pochuck gneiss are in turn found to contain varying precentages of granitic minerals derived from the invading material.

In the area 1½ miles southeast of Redington scattered boulders of Pochuck gneiss show abundant pegmatitic invading material. The pegmatites are not clean-cut with sharp borders but occur as irregular stringers or streaks and in some cases more or less equidimensional masses without distinct contact surface with the invaded material. The action of pegmatitic juices has resulted in a variety of mineralogical and structural relationships. In some of the blocks found here, masses of quartz and feldspar of pegmatitic origin, eight to ten inches in thickness, contain many crystals or crystalline aggregates of hornblende, some up to two or three inches in length. In the same mass one may find tourmaline crystals. At this locality one tourmaline crystal between two and three inches long was found in an aggregate of quartz and feldspar grains which also contained hornblende crystals. The entire mass was stained by epidote derived from the alteration of calcic plagioclase, and hornblende and pyroxene both in the Pochuck parent rock and the pegmatitic material.

Half a mile to the east of the above locality, along the electric transmission line which passes across the hills at this point, blocks of Pochuck, which were broken and dug up in the foundation of the transmission line towers, show numerous contorted layers of Pochuck material which have been invaded by the Byram granitic minerals. At several other localities in the county similar material occurs wherein discontinuous layers or schlieren of Pochuck material are scattered through Byram material which contains some assimilated and recrystallized Pochuck minerals. These schlieren and discontinuous streaks may be contorted into S-shaped forms or may as a group exhibit folding in the mass. They indicate that the invaded material was reduced to a plastic condition by the granitic magma and the whole mass was in places deformed during the processes of injection and assimilation.

The nature of some of the alteration processes which have acted on the Pochuck gneiss may be better understood if an altered phase of this material is described in detail. A specimen obtained two miles south of Redington appeared in the hand specimen as a dense granulose

greenish rock apparently containing considerable epidote and disseminated grains of garnet. This same type of material has been observed in other parts of the county and is recognized as a phase of the Pochuck gneiss that has suffered considerable alteration. In thin section the material is finely granitic in texture, the size of grain ranging from a few tens of microns in the granular aggregates to a millimeter or more in the main mass of the rock. The rock is massive and exhibits many areas of alteration granules that give a clouded appearance to much of the material. The minerals now found in the rock are chlorite, sericite, epidote, zoisite, quartz, magnetite, garnet, titanite and apatite. The first three are abundant throughout the specimen and occur as alteration materials from the earlier mineral assemblage. Going back to the original nature of this material and basing the mineral composition not only upon the present alteration products but also upon the knowledge of the composition of other phases of the Pochuck, we conclude the original minerals to have been andesine-labradorite and pyroxene as the primary minerals of greater abundance. Associated with these were smaller amounts of magnetite, apatite and titanite as accessory minerals. The presence of garnet and titanite, and areas which were surely plagioclase (now entirely altered to sericite and epidote), is the evidence for the statement that the primary minerals were metamorphosed under higher grade conditions of the hypo-zone, into a new assemblage which included oligoclase-andesine, garnet and titanite, with, of course, some magnetite as a likely accessory. This process supposes that the pyroxene was altered largely to garnet and the original plagioclase to oligoclase-andesine with or without changes in lime. The primary pyroxene may have been titaniferous, which gave rise to some of the titanite found in the later rock. A second metamorphic process that was dominantly hydrothermal under lower temperature and pressure conditions of the upper meso-zone or epi-zone, has resulted in the alteration of garnet to both epidote and chlorite and the change of plagioclase to an aggregate of sericite and epidote. Some quartz likely was introduced by the solutions that occasioned these changes. Silica may have been liberated from earlier minerals during the metamorphic changes but the clean-cut border relations of some of the quartz areas would indicate this material to have been introduced. It has been the writer's experience in observing that where the quartz in materials of this type has formed as a result of silica set free by metamorphic processes the quartz areas usually grade into other mineral areas by feathering out or by intimate interpenetration, whereas introduced silica, although commonly occupying irregular areas, has a tendency toward more clean-cut borders.

To summarize and review, the following sequence of events has been postulated.

(1) The original Pochuck rock was composed of andesine-labradorite and pyroxene with smaller amounts of magnetite and titanite.

(2) High temperature and pressure metamorphic processes possibly of a hydrostatic nature, resulted in the recrystallization of the primary minerals into oligoclase-andesine, garnet and titanite.

(3) A second metamorphic stage of development altered this second list of minerals to produce epidote, zoisite, chlorite, sericite, quartz and magnetite. Titanite is also present.

(4) Accompanying or possibly following this latter metamorphic period, quartz was introduced.

The second period of metamorphism of the above rock was apparently a true case of retrogressive metamorphism, the chief diapthoritic changes being the replacement of garnet by epidote and chlorite, and the alteration of the plagioclase to sericific mica and epidote.

Byram Granite Gneiss

Distribution.—By far the greatest area in the pre-Cambrian part of Northampton County is underlain by the Byram gneiss. It occupies broad belts in the hills in the southern part of the county and in places is practically the only rock throughout an area of several square miles. In addition to these more extensive occurrences, it occurs as intrusive bands or streaks cutting the larger areas of Pochuck gneiss. Its general distribution then is that of an invading mass which has engulfed and more or less surrounds all the older pre-Cambrian formations.

Lithologic characteristics.—Even in areas of less than a square mile, the Byram gneiss shows great variation in composition, texture and structure. Depending upon the amount of assimilated Pochuck or other earlier pre-Cambrian material, the Byram ranges from its pure form to various types of mixed rocks. The normal texture is average granitic, but finely granitic as well as coarsely granitic facies appear. In many areas the Byram is massive but in other places it has a rude streaking or an indistinct discontinuous banded appearance. Generally speaking, the more common types are those that are massive with slight streaking. The streaks are due to at least two causes. In some outcrops the orientation of the darker mineral particles likely is the result of flow during consolidation of the mass. In other localities the streaks are the remnants of former bands in the Pochuck gneiss, or other formations older than the Byram, in which a planar schistosity had been developed previous to their invasion and assimilation by the Byram. In many places the Byram shows well developed sets of joints.

Name and correlation.—The Byram gneiss was named by Spencer[55] from Byram Mountain in New Jersey where the formation is extensively exposed.

In the New Jersey Annual Reports of the 1880's, granitic and quartz syenitic rocks of several types were described. One of these descriptions from the Annual Report of 1886[56] is as follows:

Quartz Syenite. This characteristic rock of many Massive areas has been given considerable attention. Thin sections were prepared for microscopical examination by Mr. James F. Kemp, who has furnished the following descriptions of typical specimens:

I. Field No. 234, from a Massive area on the New York and New Jersey State line, between mile-posts 23 and 24, east of Greenwood Lake. The rock consists of Orthoclase, Quartz and Hornblende. The Orthoclase is filled with curious inclusions of irregular prismatic shape, which have optical properties indicating them to be some mineral, and not a glass nor hollow spaces. The Hornblende is very dark colored, and unless ground exceedingly thin, is almost opaque.

It is interesting to note that what was surely the perthitic intergrowth of orthoclase and albite was described but not completely understood.

In the reports of that time the different rock formations often were described without giving them locality names. In the Franklin Furnace folio, Spencer and others used the term Byram gneiss to describe the rocks occurring characteristically in Byram Township, Sussex County, New Jersey. They[57] included

Several varieties of granitoid gneiss which are lithologically related by the presence of potash bearing feldspars among their principal mineral components. As thus defined, the formation includes the "Hamburg," "Sand Pond," and "Edison" gneisses, which were separately mapped by Wolff [58] in the Franklin Furnace district; the "Oxford type" of gneiss, described by Nason; [59] and the gneissoid granite of Breakneck Mountain, of the Hudson, described by Merill.[60]

Bayley[61] discusses the Byram as follows:

Character and varieties.—The several phases of the Byram gneiss differ greatly in appearance, but as seen in outcrop most of them resemble one another more than they do the Losee or Pochuck gneisses. Of the two principal varieties observed one is dark gray and moderately coarse-grained and has a bronzy-brown tone on freshly fractured surfaces. It is composed essentially of microperthite, microcline, orthoclase, hornblende, quartz, magnetite, and in some places biotite. The dark minerals are ordinarily grouped into pencils arranged parallel to the strike of the rock bands. This grouping produces a gneissoid appearance on all fractured surfaces except that transverse to the axes of the pencils, where the structure appears evenly granular. The axes of the pencils pitch in the same direction as the axes of the ore bodies in the various magnetite mines throughout the region. This structure, which is characteristic of nearly all the gneisses in the district, is known as linear structure. Its strike in the region is generally N. 15-40 ° E.

The second variety of the rock is yellowish in outcrop, and pink, light

[55] Spencer, A. C., and others, op. cit., p. 5.
[56] Britton, N. L., op. cit., p. 102.
[57] Spencer, A. C., and others, op. cit., p. 5.
[58] U. S. Geol. Survey, Eighteenth Annual Report, pt. 2, p. 439, 1898.
[59] Annual Report Geol. Survey of New Jersey for 1889, p. 30.
[60] U. S. Geol. Survey Geol. Atlas, New York City folio (No. 83), 1902.
[61] Bayley, W. S., and others, op. cit., p. 70-71.

gray, or nearly white on fresh fractures. It is ordinarily finer grained than the dark-gray variety, from which it differs mineralogically mainly in the subordination of dark components and thus the rock lacks the pencils of the darker variety and consequently does not show the distinct pitch structure. It may possess a slight linear structure, but as a rule this is so obscure that the texture of the rock is practically granitic.

In the Raritan quadrangle both phases of the Byram occur but not generally in distinct areas. The first or darker-colored phase is much more abundant than the lighter phase. It comprises the entire body of some of the belts, as that immediately west of Cranberry Reservoir, and the greater portion of all the others. The lighter phase is limited to narrow layers interlaminated with the darker variety and with layers of the Losee and Pochuck gneisses.

Intermediate phases between the Byram and the other gneisses have intermediate characteristics.

Mineral composition.—In mineral composition the Byram gneiss differs from the Losee gneiss in its larger proportion of potassic feldspars, particularly in the form of microperthite, and from the Pochuck gneiss in its smaller proportion of hornblendic and pyroxenic minerals. It commonly consists of quartz, microperthite, microcline, orthoclase, a little brown hornblende, magnetite, apatite, and sphene. Diopside and hypersthene occur in some phases but are not common. Biotite is generally present, in some specimens in large quantity. It is commonly associated with hornblende, but in a few specimens it is the only bisilicate found.

The Byram gneiss grades into the Losee gneiss by introduction of oligoclase and into the Pochuck by increase in oligoclase and bisilicates.

Wherry, in an unpublished manuscript, in discussing this formation states as follows:

Character.—The rocks grouped under the name of Byram gneiss are rather variable in makeup and aspect, but the most typical phase is a coarse-grained, pinkish-gray, obscurely banded gneiss, which weathers into bronzy-surfaced round or flattened bowlders. Locally it may be fine-grained or take on a greenish, yellowish, or gray color. Feldspar is the most prominent constituent, but quartz is also usually present in large amount. Hornblende is the commonest dark mineral, but augite, biotite and magnetite or ilmenite are not infrequent, and locally any one of them may become abundant. Greenish sericitized phases occur in several places.

Quoting further from the same manuscript regarding the Losee gneiss, which was described[62] in New Jersey as a quartz, oligoclase rock with small amounts of biotite and (or) hornblende, "Only two very small areas of the Losee have been observed on the Allentown quadrangle, on South Mountain one mile south and a like distance east of Emmaus, respectively." More recently Wherry has stated in a personal communication, his belief that these areas, too, might better be described as phases of the Byram gneiss. From a survey of the work of previous students of the pre-Cambrian gneisses of Pennsylvania and New Jersey, it will be noted that the numerous early granitic formations have been grouped under a gradually decreasing number of formational names.

In the present publication, all the granitic rocks characterized by the presence of quartz and alkali feldspar have been mapped as Byram

[62] Wolff, J. E., and Brooks, A. H., op. cit., p. 440.

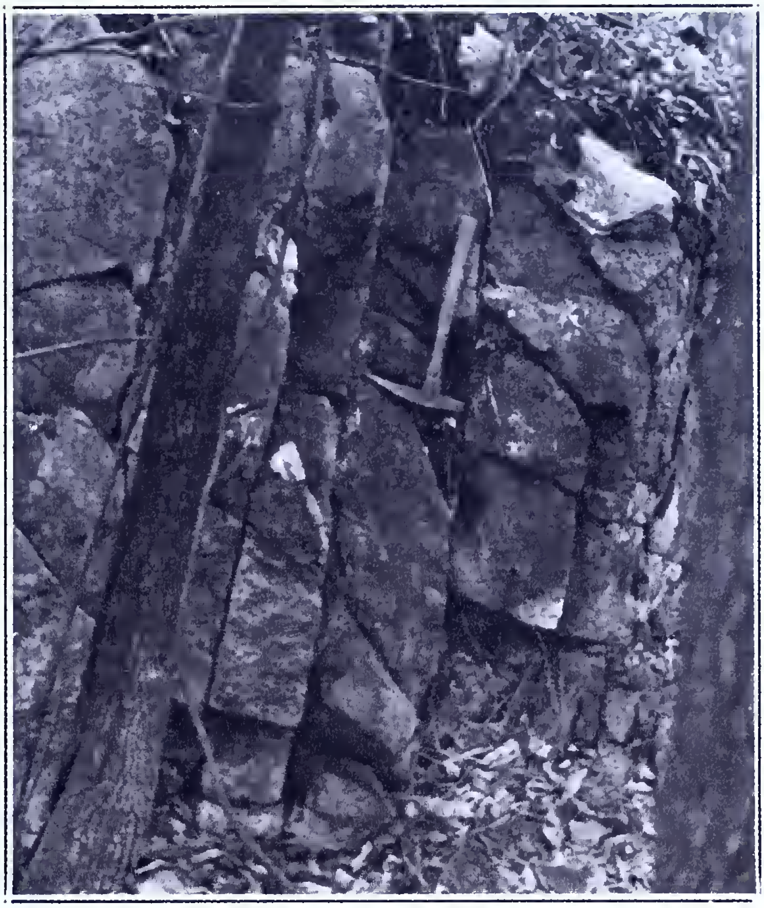
gneiss. This group, therefore, includes that granitic material which is thought to represent the pure Byram made up of quartz, microcline, and microperthite, as well as a large number of variations of this typical material, which changes are for the most part dependent upon varying amounts of material assimilated from the invaded rocks. Under the name Byram has also been included pegmatitic granitic bodies and irregular pegmatitic masses.

The exact age of the Byram gneiss is unknown but it is younger than the Franklin formation, the Moravian Heights formation and the Pochuck gneiss because all these are intruded by granitic material of the Byram. These older formations have been thought to represent the late Archæozoic or Huronian. The Byram granite gneiss shows much less metamorphism than do these older formations. Pegmatitic differentiates of granitic material cutting the older formations, the Byram gneiss, and in at least one area the Hardyston quartzite, would indicate either a continued period of pegmatitic emanation or successive periods of such introduced material. With these thoughts in mind, it is suggested that the Byram granitic material is of Proterozoic age with some of the pegmatitic injected material likely of late pre-Cambrian time and some of it definitely post-Hardyston in age. It could, therefore, be correlated with any of several of the Proterozoic intrusive masses found in the pre-Cambrian area of Canada but there is no definite evidence as to its exact position in the geologic time scale.

Stratigraphic and structural relations.—The relations of the Byram granitic material to other formations in the district are quite distinct. Granitic materials, including pegmatites, with two exceptions to be discussed under Local Details, are all older than the Paleozoic sedimentary formations. The indications are that the older pre-Cambrian formations had been formed in the region and were metamorphosed before the emplacement of the Byram gneiss. An erosional period occurred some time later, which exposed the Byram so that Paleozoic sedimentation was inaugurated on the eroded surface of the pre-Cambrian formations.

The general structural relations of the Byram to the other pre-Cambrian formations is one of intrusion and invasion along the previously formed structural planes of the older formations. The present scattered and in general small areal occurrence of the older formations indicates that the erosion that followed the introduction of the Byram reached to considerable depths. This resulted in the removal of most of the volume of the invaded material and at present the largest part of the area is occupied by Byram with a smaller total area made up of

PLATE 10.



A. Jointing in Byram granite gneiss.

B. Jointing in Byram granite gneiss. Crest of Green Hill, southeast of Freemansburg.

streaks and lenticular remnants of Pochuck gneiss, and the Moravian Heights and Franklin formations. The chief exception to this is the larger area of Pochuck material which is found in the pre-Cambrian belt southwest of Easton occupying an area of several square miles in the vicinity of Hexenkopf Hill. Without being consistent throughout the area but nevertheless showing a tendency toward a definite orientation, the gneissic structure in the Byram trends along an east-northeast to west-southwest line. This trend was determined by the previously existing structure of the older pre-Cambrian formations and was inherited by the Byram during its invasion.

Petrography and petrology.—As has been stated, the Byram varies considerably in its composition. The minerals of the facies that has been thought to represent the pure type are quartz, microcline, soda microcline, microperthite, orthoclase and small amounts of apatite and magnetite. Material of this composition is exposed on the east side of the Bath Pike where that road cuts through the western end of Pine Top, a hill two miles north of Bethlehem. It is interesting to note that Byram of this type is the country rock in the vicinity of Replogle mine of the Alan Wood Company at Dover, N. J. The same material occurs in other places in the pre-Cambrian belt of New Jersey and occurs, of course, in several localities in Northampton County. It is thought, therefore, that this represents the purer uncontaminated material of the Byram granitic invasion which, on the basis of its extensive distribution, must have been of considerable volume.

Analyses of rocks of the Byram type from Pennsylvania and New Jersey

	1	2	3	4	5
SiO_2	77.07	58.75	61.54	73.64	64.64
Al_2O_3	12.61	17.16	17.98	12.82	15.92
Fe_2O_3	.71	5.18	3.11	.65	1.14
FeO	.73	3.94	3.21	1.55	4.65
Mg O	Trace	.91	.32	.12	.23
CaO	.87	.62	2.29	1.08	2.12
Na_2O	3.43	5.72	5.85	2.47	4.38
K_2O	4.06	5.40	4.77	6.22	6.06
H_2O	.23	.35	.09	.14	.04
H_2O+	.62	.73	.78	.68	.43
TiO_2	.12	.65	——	.17	.42
CO_2	Trace	.13	.42	.38	——
P_2O_5	Trace	.20	.18	.04	Trace
MnO	.09	.10	.08	.03	.03
BaO	——	——	——	.04	.10
ZrO_2	——	——	——	——	Trace
S	——	——	——	None	.06
Trace?	100.54	99.84	100.62	100.03	100.22

1, 2, 3, from U. S. Geol. Survey Geologic Atlas, Raritan folio (No. 191), p. 9, 1914, (field edition p. 73). 1. Quarry a mile west of Hibernia, 2, 3. Van Nest tunnel, Delaware, Lackawanna & Western Railroad, near Oxford.

4, 5, from Geology and Mineral Resources of the Quakertown-Doylestown District, Pennsylvania and New Jersey. U. S. Geol. Survey Bull. 828, p. 14,

1931. 4. Quartz monzonite (Byram). West end of Furnace Hill, Boyertown quadrangle, Pa. 5. Quartz monzonite (Byram). South of Ludwigs Corner, Phoenixville quadrangle, Pa.

Other types of the Byram range from the pure original material into facies which include abundant hornblende and plagioclase feldspar commonly of oligoclase or oligoclase-andesine composition. In addition, varieties containing biotite and hornblende with plagioclase feldspar of the more sodic types are found. Magnetite is more abundant in the rocks containing hornblende and often the percentage of apatite also increases. The pegmatitic material associated with the Byram gneiss is typically a quartz, orthoclase or microcline rock.

Local details.—Bunco Hill, 1½ miles east of Hellertown, and the other parts of the ridge that extend about 2½ miles east from the valley at Hellertown, is composed of a rock that has been mapped as Byram but is somewhat different than other phases of the Byram in that it is coarse-grained and tends toward a diorite in composition. The outcrops in this area in general show linear parallelism in the rather coarse-grained granitic rock. The rock is composed of quartz, orthoclase, oligoclase and hornblende. The orientation of the hornblende has resulted in a linear parallelism pitching to the northeast. The average of several measurements of this structure gives the pitch as 40° in a direction N. 50° E.

Pegmatitic Material

Pegmatitic material is often found on hill slopes as float fragments occurring with more abundant blocks of Byram or Pochuck gneiss. Where masses of pegmatite are exposed they commonly show gradational contacts with the intruded formations, and for the most part occur as irregular masses with no definite form.

Lithologic characteristics.—In hand specimen the pegmatitic material varies from coarsely crystalline microcline or (and) orthoclase with associated quartz and hornblende or biotite to types that are essentially pegmatitic granites composed of orthoclase, microcline and quartz with or without smaller amounts of hornblende or biotite. Many of the pegmatites associated with the Pochuck contain oligoclase or oligoclase-andesine in abundance. This material, and the recrystallized hornblende associated with it, has been derived by assimilation from the Pochuck gneiss, and represents a product of intermediate composition.

Age relations.—The intrusive relations of the pegmatites to other formations, including the Byram gneiss, indicate their later age. They are unquestionably to be regarded as having been formed through a great range of time. Some pegmatitic masses were intruded

into the Byram and were later eroded to form in part the surface on which Paleozoic rocks were deposited. In at least one place pegmatitic material of post-Hardyston age indicates the invasion of the area by material of this type in earlier Paleozoic time. The range therefore through which pegmatitic material was introduced into the pre-Cambrian area of Northampton County extends from the period following the invasion of the Byram to a post-Hardyston time.

Paleozoic Igneous Activity

Evidence of albitization.—A fine-grained granulose rock found in the Saucon Valley about one and one-half miles north of Hellertown has presented some difficulties in the interpretation of its origin. The material in question occurs toward the eastern end of the south slope of the low ridge extending eastward from the roundhouse of the Reading Railroad Company. In hand specimen it equally resembles an arkosic quartzite and a medium-grained granite. The area is separated from the ridge to the southeast by a narrow valley and it is, therefore, not possible to trace the formation eastward and there to determine its relationship to the Hardyston and Byram gneiss, both of which occur a short distance to the southeast.

The grain size ranges from 0.3 or 0.5 mm. to several millimeters in diameter. This variation, together with the arkosic composition of this supposed sedimentary formation, gives the rock an igneous or granulose metamorphic appearance.

One specimen showed a zone of interpenetration of the sedimentary material with a second material having an igneous appearance. The contact between these two types was irregular, somewhat sawtoothed in appearance, the toothlike projections varying from ¼ to over 1 inch in length. In some places the toothlike extensions of the sediment seemed to die out in the igneous material as the result of assimilation. Megascopically the hand specimen was light gray and medium-grained, the grain size in the igneous material being somewhat greater than that of the sedimentary part but both of them on the order of a sizable fraction of a millimeter or a millimeter or two in diameter.

Under the microscope the relations between these two types of rock were found to be much as indicated by the hand specimen. The supposed sedimentary material proved to be composed of rounded and subangular, more or less eliptical grains of quartz, orthoclase, microcline, and oligoclase. Fewer grains of apatite, tourmaline and zircon also appeared. A network of sericite in places stained with hydrous iron oxide occupied intergrain areas. Rude but nevertheless definite bedding was observed. The part of the specimen that contained the

introduced igneous material was made up of quartz, orthoclase, microcline and albite. This last mineral occurred as zones of extended growth around both orthoclase and microcline grains. The magmatic material altering this rock apparently encroached upon an arkosic sediment and assimilated it in part. The contact between the two types of rock is irregular and in detail resembles the hand specimen appearance in that it is of a zigzag or sawtooth type. The projections of the original sedimentary type of rock into that part altered by igneous action die out gradually where they were assimilated by the invading material. Stringers of sericite sometimes reach from the ends of these teeth into the altered rock. There is more sericite in the sedimentary than in the igneous material.

This single specimen introduces several lines of thought which give rise to a considerable field of interesting speculation. Considering the ages of the two materials involved, we are confronted with the following situations.

Supposition 1.—If we assume that the sedimentary material is the equivalent of the Hardyston and therefore Cambrian in age, we thereby postulate the presence of a post-Hardyston invasion of granitic juices in the area. Such an invasion has been heretofore suspected. The finding of pegmatites[63] in the end of Morgan Hill has indicated the proximity of granitic material to the contact between Hardyston and pre-Cambrian, in post-Hardyston time. Other than this, however, there has been no direct or implied evidence of a Paleozoic granitic intrustion.

Supposition 2.—Assuming that the sedimentary material is pre-Cambrian gives us the following relationships. If it is pre-Cambrian and is made up of detrital materials derived from the Byram gneiss, we must propose an age for the formation which is later than at least some part of the Byram intruded material. Recognizing also that the sedimentary formation has been invaded by granitic emanations of alkali-silicic type, which would be the expectable composition of emanations from the Byram, serves to introduce the following conceptions. The Byram granitic invasion must be interpreted as having occurred throughout a considerable geological interval or we must assume a repetition of a high soda granite magma occurring through a considerable period of time extending from pre-Cambrian to post-Hardyston. This would necessarily follow if we admit the invasion of one facies which was then exposed by erosion and suffered the deposition of a sedimentary series which was later sufficiently buried to allow a granite magma to invade the formation, at a depth great

[63] Fraser, D. M., Paleozoic Pegmatites in the Pennsylvania Highlands: Am. Min., vol. 21, No. 10, pp. 662-666, 1936.

enough to result in a rock of granitic texture. To repeat, this would mean: (1) igneous intrusion with cooling conditions such that a granitic-textured rock resulted; (2) deep-seated erosion and the deposition of sediments formed from the detritus of the previously emplaced material; and (3) a second igneous invasion which also occurred at sufficient depth to produce granitic texture.

A sedimentary series of pre-Cambrian age has long been recognized and is known as the Moravian Heights formation. Every occurrence of the Moravian Heights in Northampton County and in the adjacent region shows a much more highly metamorphosed material than that described above. In all cases where true Moravian Heights material is found, the supposed original argillaceous quartzose rocks now appear as quartz-sericite-sillimanite schist. The distinct difference between the Moravian Heights and the sedimentary material in question would certainly point to a much younger age for the latter. Reviewing the points brought out under suppositions 1 and 2, we are confronted with one of the following conclusions. (1) A post-Hardyston invasion of granitic juices which resulted in albitization of an earlier sediment, or (2) a post-Moravian Heights pre-Cambrian sedimentary series.

The writer believes that proposal No. 1 is the more reasonable. In no other area in the vicinity of Northampton County have we found remnants of a pre-Cambrian sedimentary series younger than the Moravian Heights. It would seem reasonable to expect such outcrops to occur if such a series had ever been formed. This is especially true if we remember that the Moravian Heights formation, which would necessarily be much older, does occur in several places. On the other hand, the occurrence of the pegmatitic material in Morgan Hill is at least one other indication of igneous activity in post-Hardyston time. It is the writer's conviction that much of the silicification of both pre-Cambrian and Paleozoic rocks of this and adjacent counties has resulted from the intimate penetration of the entire district by silica solutions of magmatic origin which in some cases carried silicates as well. It is therefore expectable to find some of the lower Paleozoic rocks containing introduced material derived from a magmatic source of granitic composition.

The occurrence of the albite as well as the relationships of some of the quartz areas in the igneous material invading the sedimentary rock should also be described. As was stated, the albite (and potash feldspar to a lesser extent) often occurs as rims around orthoclase or microcline grains. These rims, of course, extend to the third dimension and result in shells of albite surrounding the other grains and are, therefore, spheres of added growth. They might have been

formed as a result of end-stage activity within the invading material, in which case the grain core as well as the shell would have been introduced by the later igneous action. It may also be suggested that they resulted from the later introduction of albitic-silicic material somewhat more hydrothermal than magmatic in origin. This latter view seems the more likely because of the similarity of the grain material found as cores of the introduced albite and the grains in the adjacent arkosic sediment. Not only are the grains of each largely made up of perthite, microcline, soda microcline, orthoclase and quartz but they also show a comparable development of strain shadows and other structural features indicating a similar stress history. We conclude, therefore, that the albitic rims or spheres represent an end-stage phase of the consolidation of magma, the albitic material being introduced in its present position by the hydrothermal process of albitization. In places, albite having optical continuity surrounds two grains of orthoclase, which grains show different optical orientation. Relationships such as those listed indicate the development of the albite subsequent to the deposition of the included grains.

Areas of quartz within this same rock often occur as irregular patches with round budlike projections encroaching upon other minerals. They are obviously not the more or less irregular, but dominantly equidimensional grains which would be expected to form by the crystallization of quartz in interstitial areas resulting from the normal crystallization of a granite. They, of course, could have been formed by recrystallization and encroachment of quartz upon other minerals during a period of metamorphism which could have given rise to the types of contacts observed, without subjecting the rock to cataclastic processes or complete recrystallization. A second interpretation would be to suggest that the quartz areas as observed were introduced at the time of albitization. Under this latter condition the irregular areas with the rounded projections would have resulted chiefly from replacement of previously existing minerals. The former view is in part supported by the suggestion that the albite rims may also have resulted from a recrystallization under the influence of raised temperature and pressure. These rims, however, are not found consistently around the orthoclase and microcline grains, and further in some places the earlier minerals are obviously largely replaced by the albite rim. The indications are, therefore, that it was actually, in part at least, a replacement action rather than being dominantly a form of exsolution or similar processes.

Quartz areas of the above type occur so abundantly in the rocks of the pre-Cambrian belt, and are so numerous in those specimens which, megascopically, are obviously silicified, the writer concludes that much

of these irregular quartz grains with their round budlike projections have resulted from the invasion and replacement of other materials by quartz.

Pegmatite

Pegmatitic material cuts the Hardyston quartzite in the northeastern end of Morgan Hill about a mile and a half southeast of Easton. In this district the Hardyston quartzite dips to the northeast and north away from the pre-Cambrian rocks of the ridge. An old roadbed cuts the hill along its northeastern, eastern and southeastern slopes, and it is along one of these road cuts that the pegmatitic dikes are exposed.

It is apparent that pegmatites of Paleozöic age would be distinguished with difficulty in the areas of pre-Cambrian rocks and only where one is fortunate enough to find them actually cutting Paleozoic sediments may their later age be recognized.

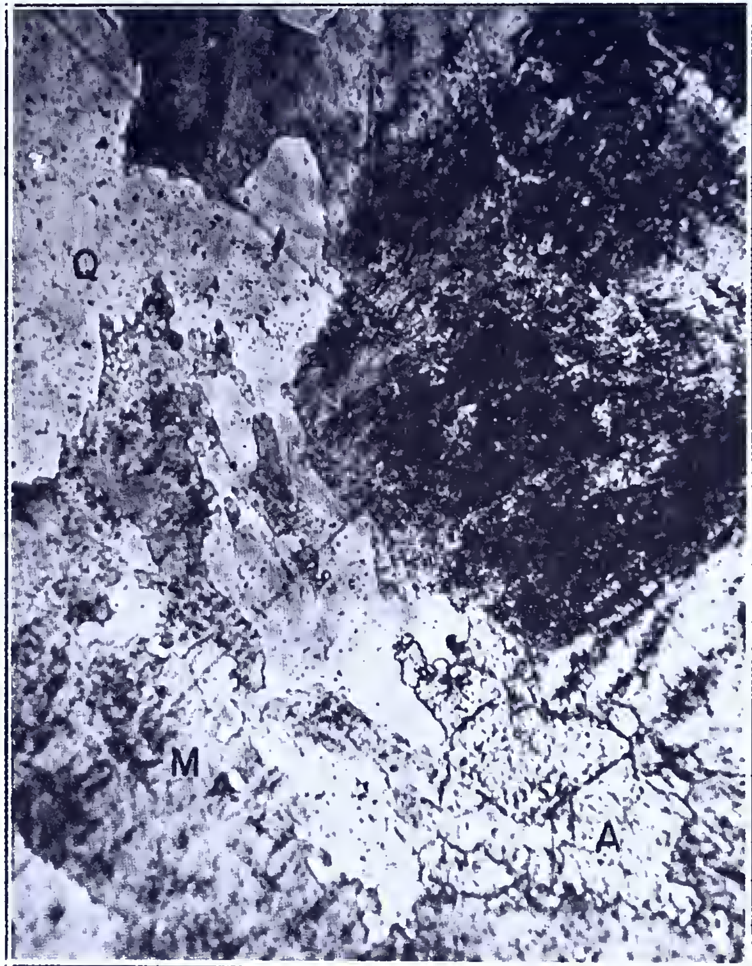
The pegmatitic material observed in the Hardyston varies from sub-horizontal irregular lenses, changing in a horizontal distance of less than ten feet from a maximum of five or six inches to less than an inch in thickness, to small dikes extending vertically and sending off small spur-like apophyses that have filled what were apparently gash joints.

The proportional amounts of feldspar and quartz vary considerably. In hand specimens feldspar appears in some places relatively free from other minerals, and in others it is intimately mixed with quartz which may, and often does, make up a large percentage of the dike.

Petrography.—In thin section, microcline is found lining the dike walls and extending into the dike proper in irregular masses. It contains occasional grains, or aggregates of grains, of apatite and in spots is extensively replaced by quartz. The quartz may occupy the entire dike except for small amounts of ragged microcline remaining along the walls. In other places quartz has encroached upon microcline and has penetrated this mineral as arms and irregular areas. The edges of some microcline grains contain many small circular areas and concave encroachments of quartz.

Along the walls of the dike, which are much more distinct than the contacts of pre-Cambrian dikes with their wall rocks, grains of feldspar in the sandstone show extended growth, as do also occasional grains of tourmaline.

It is concluded from these features that at first microcline and apatite entered and filled the fractures. At this time some feldspar grains, and probably the tourmaline also, grew in the wall rock.



A. Quartz (Q) cutting microcline (M) and apatite (A). All three belong to the pegmatite.

B. Quartz (Q) from the pegmatite cutting microcline (M) of the Hardyston.

PHOTOMICROGRAPHS OF PEGMATITIC MATERIAL CUTTING THE HARDYSTON IN THE EASTERN END OF MORGAN HILL. x60

Quartz then entered, permeated the vein material and extensively replaced the microcline.

It is likely that the dikes where now found indicate the upper limit reached by the pegmatitic juices; with depth the filling more and more closely approached vein formation. Their igneous affiliations, however, are fairly definite.

The pegmatitic material of Morgan Hill was recognized before the albitized material occurring northeast of Hellertown was studied and understood. With the finding of this latter material comes corroborative evidence of the existence of magmatic emanations during early Paleozoic time.

The abundance of quartz veins in the region and the extensive silicification of the Hardyston and the pre-Cambrian rocks indicate that the entire Highlands, and the limestone and shale areas adjacent, have been subjected to an extensive permeation by silica-bearing solutions. Much of this material that has previously been tentatively assumed to be of meteoric origin, may well be of magmatic origin.

In addition, it should be pointed out that there is now a source for magmatic solutions that may have formed the zinc deposits at Friedensville, as well as other zinc and lead deposits of eastern Pennsylvania, which have been thought to lie outside the areas invaded by such solutions.

Metadiabase

A fine-grained, dense, greenstone type of rock is found in float blocks on the north slope of Kohlberg near its western end. This is the only place this rock was found in Northampton County. It occurs in increasingly abundant areas as one passes through Lehigh County into Berks County to the southwest. The hand specimen found on Kohlberg appears to be an altered basalt. It is greenish black and even though fine-grained gives the impression of having a matted structure.

Mineralogic composition.—The microscope shows that this rock is composed of secondary feldspar, epidote, chlorite, magnetite, and introduced quartz. The primary minerals are interpreted to have been augite, labradorite and magnetite. These have been changed hydrothermally to the above list of alteration minerals. It is likely that the quartz is largely introduced although some smaller grains may have been formed from the hydrothermal breaking down of the previously existing minerals. In general, however, the quartz areas are irregular and have somewhat rounded contacts with other minerals. This has led the writer to believe the quartz was introduced because if it had been formed from the primary minerals, more intimate inter-

growth relations would likely have resulted. Furthermore, the silica content of the original diabasic or basaltic material likely was too low to result in the present mineral assemblage plus the frequent areas of quartz.

The structures shown under the microscope include a trachytoid arrangement of labradorite laths in a fine-grained groundmass of augite, magnetite, and andesine-labradorite, flow-structure due to the parallel arrangement of andesine-labradorite laths and the more common diabasic and ophitic structures.

Age relations.—Little is known about the age relations of this basic material to other rocks in Northampton County. In the area to the southwest in Lehigh and Berks Counties, however, the occurrence of similar material in areas of pre-Cambrian rocks and Hardyston quartzite would indicate its association with both Paleozoic and pre-Cambrian formations. The following seven paragraphs from a paper[64] describing this material will give the reasons for considering it to be of probable Ordovician or post-Ordovician age.

Rocks of this type have long been recognized in the pre-Cambrian belt of eastern Pennsylvania. In Berks County in the area north of Boyertown and extending into the southern part of Lehigh County, altered diabasic rocks were recognized and described[65] in 1917, when they were considered to be pre-Cambrian in age. More recently[66] one dike of this material has been indicated as Triassic in age. In the absence of any conclusive evidence regarding the age of these rocks, it seems desirable to sum up the similarities and differences existing between them and the pre-Cambrian Pochuck gneiss and the Triassic diabase. With this thought in mind, the relations of this greenstone to the other basic rocks are discussed below.

Comparison with the Pochuck gneiss.—The greenstone, which may be called a meta-diabase or meta-andesite, is commonly associated with the Pochuck gneiss in the field and was at first thought to represent a facies of this formation. From the thin-section studies, however, it was found that the greenstone contains augite and andesine or andesine-labradorite while the Pochuck typically carries hornblende in addition to augite and andesine. Furthermore, the greenstone is altered by hydrothermal processes to epidote, chlorite, sericite, and saussurite, whereas alteration of the Pochuck produces uralite and sericite, and, except locally, only small amounts of epidote and chlorite.

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[64] Fraser, D. M., Basic Rocks in the Eastern Pennsylvania Highlands: Am. Geoph. Un. Trans., 18th An. Meet., 1937.

[65] Jonas, Anna I., Pre-Cambrian and Triassic Diabase in Eastern Pennsylvania: Amer. Mus. Nat. Hist. Bull., vol. 37, pp. 173-181, 1917.

[66] Bascom, F., Wherry, E. T., Stose, G. W., and Jonas, A. I., Geology and Mineral Resources of the Quakertown-Doylestown District, Pennsylvania and New Jersey: U. S. Geol. Survey Bull. 828, plate 1, 1931.

It would seem reasonable, therefore, on the basis of different mineralogy, the different metamorphic structures, and the different alteration products, to assume a different origin for these two rock types. The most reasonable interpretation is, of course, that the greenstone is later than the pre-Cambrian Pochuck gneiss, has been intruded into it, and has been hydrothermally altered only, whereas the older formation, whatever its original nature, has been subjected to complete recrystallization as the result of dynamic metamorphism and later has been only slightly altered by hydrothermal action.

Comparison with the Triassic diabase.—Triassic diabase examined in a number of sections has been found to show relatively unaltered feldspars and augite, with little evidence of hydrothermal alteration. The quartz present in this rock is commonly in the form of micrographic intergrowths and does not contain blebs or irregular areas replacing the other minerals. The greenstone (meta-diabase and meta-andesite), however, as has been stated, is always altered by the breaking down of the feldspars to sericite and saussurite and the alteration of augite to chlorite and epidote. In several sections of the greenstone, quartz occurs in rounded or irregular areas. Very probably it was introduced by hydrothermal solutions which brought about the change to the greenstone. Skeletal magnetite crystals are abundant in the greenstone, and pyrite occurs in many of the specimens.

With reference to the relative ages of the Triassic diabase and the greenstone, attention is called to the much cleaner, unaltered appearance of the Triassic rock as contrasted with the typically altered greenstone. Furthermore, it would seem that, if solutions following the Triassic invasion were capable of travelling along small dikes of basic material in the pre-Cambrian, causing the hydrothermal alteration shown by the specimens, there should be considerable evidence of some alteration in the larger diabase areas associated with the sandstones and shales of Triassic age. Such alteration, however, is lacking. For these reasons the greenstone has been regarded as being older than the Triassic diabase and is thought to have been hydrothermally altered before the emplacement of the Triassic diabase.

Comparison with Ordovician and post-Ordovician basic rocks.—Specimens from Jonestown[67], where both diabase and basalt flows of Ordovician age occur, have been examined and found to show a similar type of hydrothermal alteration resulting in meta-basalts and meta-diabases similar in their mineralogy to the greenstones in question.

[67] Gordon, Samuel G., Ordovician Basalts and Quartz Diabases in Lebanon County, Pennsylvania: Proc. Acad. Nat. Sci. Phila., pp. 354-357, 1920; also George W. Stose and Anna I. Jonas, Ordovician Shale and Associated Lava in Southeastern Pennsylvania: Geol. Soc. America Bull., vol. 38, pp. 505-536, 1927.

The specimens from the Jonestown area as well as those from Lehigh and Northampton Counties show alteration of the feldspars to sericite and saussurite, and the breaking down of the augite. The resulting rocks have a green cast and are equally hard, dense rocks typical of the partial hydrothermal alteration of fine-grained basic igneous rocks.

Basic dike rocks of post-Ordovician age[68] from Franklin, New Jersey, were examined and also found to be quite similar. These specimens show more introduced granitic material but otherwise are like the greenstones in the Eastern Pennsylvania Highlands in having abundant chlorite and epidote and intensive sericitization and saussuritization of the feldspars.

Conclusions.—The structural and mineralogical evidence of the greater age of the Pochuck does not preclude the possibility of the greenstone being pre-Cambrian but does indicate a much later age for the greenstone. Along the same lines of evidence, it is likewise not conclusively shown that the greenstone is not Triassic in age, but, as it consistently shows more general alteration, the indications are that it is somewhat older than the Triassic. The close similarity in structure and both primary and secondary mineralogic composition of the greenstone with other rocks of known Ordovician age has led to the tentative conclusion that the greenstone represented by the meta-diabase and meta-andesite should also be regarded as Ordovician in age. If this material is so regarded, we may then consider the scattered occurrences of basic intrusive rocks of Ordovician (or post-Ordovician) age as indicating a belt of weakness in which fracturing occurred to a considerable depth, and along which basic magmatic material rose toward the surface much as similar material cut the Triassic rocks at a later time by invading deep-reaching fractures that probably resulted from faulting.

[68] Spencer, A. C., and others, U. S. Geol. Survey Geol. Atlas, Franklin Furnace folio (No. 161), 1908.

STRATIGRAPHY OF THE PALEOZOIC, MESOZOIC AND CENOZOIC ROCKS

By Benjamin L. Miller

The post-Proterozoic geological formations of Northampton County range in age from the Cambrian to those now in process of formation. However, there are several large gaps representing time when the region was undergoing degradation and contributing material for the formation of rocks in other areas. In all probability some of the missing ages were once represented within this area by rock strata that have been completely removed by subsequent erosion. Indeed, it is possible that all of the Silurian, Devonian, Mississippian and Pennsylvanian formations now present in the regions beyond Kittatinny (Blue) Mountain once continued over a part, if not all, of Northampton County, although at present the upper Paleozoic above the basal Silurian is entirely lacking.

The geological column in its entirety shows that alternately the region has existed as land and as sea or as areas of destruction and construction, the rocks now present constituting the records of submergence beneath oceanic waters, with the exception of the Pleistocene and Recent strata which were deposited on land.

CAMBRIAN SYSTEM

Rocks of Cambrian age are extensively developed in the southern portion of Northampton County. They are sharply separated from the underlying pre-Cambrian rocks, which are much older and much more highly metamorphosed. Whereas the pre-Cambrian rocks are largely igneous, the Cambrian rocks are almost exclusively of sedimentary origin. During their formation an extensive shallow inland sea covered the entire region and extended northeastward, northwestward and southwestward for hundreds of miles. The land mass that furnished the sediments that now constitute the Cambrian strata lay to the southeast. At times the shore line apparently was not many miles away but at other times the land mass which has been called "Appalachia" probably was depressed so that the shore was perhaps fifty or more miles distant.

The Ordovician rocks overlying the Cambrian strata are readily differentiated in most places but are similar in many respects, as the same general physical conditions prevailed.

As shown in the geologic table on a preceding page, three divisions of the Cambrian are recognized in Northampton County. These are, in order of age, the Hardyston which is almost entirely an arenaceous

formation, and the Tomstown and Allentown (Conococheaque) which are impure magnesian limestone formations. To the southwest the Cambrian strata have been divided into two more formations which are apparently absent in this area. Overlying the Tomstown in Franklin County there is a series of arenaceous strata, designated as the Waynesboro formation. This formation has no counterpart in the Lehigh Valley. The Waynesboro is overlain by limestones and dolomites known as the Elbrook formation. Both the Waynesboro and the Elbrook have been referred to the Middle Cambrian. In a few localities in Northampton County some magnesian limestones, here included in the Tomstown, present some features similar to some of the Elbrook strata of other regions. This has led some workers to believe that the Elbrook is present in this region and should be differentiated. Any attempt, however, to map a distinct unit as Elbrook in this region would require drawing arbitrary and confusing lines that could not be established on known field evidence.

The differentiation of the magnesian limestones of the Cambrian of the Lehigh Valley is unusually difficult and in certain localities it is impossible to be positive. The criteria for separation are almost entirely lithologic and similar features occur in each of the formations. In small exposures or in hand specimens it is generally impossible to identify the particular formation. Fossils are generally extremely rare. The complexity of structure and the absence of outcropping beds over extensive areas still further complicate the problem.

Dr. John M. Hills[69] studied the insoluble residues of some of the limestones of the Lehigh Valley in an attempt to correlate the strata and interpret the structures. He made a most detailed investigation but was forced to the conclusion "that, while the method of insoluble residues can not be recommended for independent use in regions of complex structure, it is very valuable as an adjunct to conventional field methods in determining stratigraphic succession and establishing more exact lithological correlations." (loc. cit., p. 131.)

Even this cautious statement appears to the writer as perhaps somewhat too optimistic. The shallow-water deposits of the Cambrian limestones of this region present too many local variations for this method to be reliable except in those places where outcrops are abundant, a situation that is rare in this region.

Dr. Hills' contribution to the microscopic constitution of the Lehigh Valley limestones is valuable in the consideration of their origin. Rounded quartz sand grains, light and dark-colored chert and dolocasts are common; angular fragments of quartz and occasional grains

[69] Hills, John M., The Insoluble Residues of the Cambro-Ordovician Limestones of the Lehigh Valley, Pennsylvania: Jour. of Sedimentary Petrology, vol. 5, pp. 123-132, 1935.

of pyrite, garnet, magnetite and hematite are noted in many specimens. No one of these minerals was found to be diagnostic of any particular formation, so that correlations were based on their relative abundance. In addition, Dr. Hills found some microscopic foraminifera as had B. Frank Buie previously while engaged in the study of insoluble residues of the Allentown formation.

Hardyston Formation*

BY BENJAMIN L. MILLER AND PHILIP B. MYERS

Distribution.—With the exception of a small area exposed on the south side of Camels Hump, the outcrops of the Hardyston formation in Northampton County as shown on the accompanying map are confined to that portion lying south of the Lehigh River and included within Lower Saucon and Williams Townships.

Prime[70] gives another locality at the extreme west end of the outcrop of the gneiss of Chestnut Hill where

> Potsdam (Hardyston) sandstone was seen . . . south of the blacksmith's shop at S. Seips, east of the road leading to Easton . . . In the spot colored yellow (on Prime's map accompanying his report) a shaft had been sunk in 1875, in damourite slate, and a little brown hematite iron ore found, but not enough to justify further search. Below the damourite slate Potsdam sandstone was found nearby in place, but much fractured, and below this the gneissic rock.

The writers have failed to find any surface evidence of this occurrence.

Rogers[71] reports the same formation outcropping on both sides of Chestnut Hill and gives the following description:

> Both on the south and north sides of the axis (of the hill) the Primal (Potsdam) sandstone is very well exposed. On the south side it seems to constitute a separate low arch. It is here largely displayed on the river side, and is very vitreous, much fused and generally of a reddish hue; but a white sandstone of the more normal character is associated with this.
>
> Just at the north end of the gap there is a considerable mass of Primal (Potsdam) white sandstone, forming a stoneslide or talus. In the northwest flank of the ridge, the sandstone may be seen in place dipping vertically.

It would seem from this definite description that the Hardyston must be present in the localities mentioned but Prime[72] states that he and his workers failed to find any trace of the formation there and the recent investigators have likewise failed.

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* The senior author began his study of the Hardyston formation in 1907 and has continued it ever since. Recognizing that a further investigation was desirable, Philip B. Myers, while holding a Research Fellowship in the Department of Geology of Lehigh University from 1932 to 1934, was assigned this problem. He has remapped the outcrops of the formation throughout Northampton County and with slight modifications the lines of this formation appearing on the accompanying map represent his conclusions. The following descriptions are in large measure abstracted from his unpublished dissertation, especially that portion entitled Local Details, but modified sufficiently to conform to the treatment of discussion of other formations. Mention should be made of the assistance rendered by Dr. D. M. Fraser in the microscopic investigation.

[70] Prime, F., Pennsylvania Second Geol. Survey, D3, vol. 1, p. 209, 1883.

[71] Rogers, H. D., Geology of Pennsylvania, vol. 1, p. 242, 1858.

[72] Prime, F. op. cit.

A generalized statement with only a few minor exceptions is that Hardyston strata crop out in a narrow band on the comparatively steep slopes of the gneiss hills, generally near the base although in a few places extending to the crest of the hills. In the latter instance, the dip is practically the same as the slope of the hill so that the Hardyston forms a thin cover to the hill. Generally, however, the strata dip at considerably greater angles than the slope of the hill so that the width of the outcrop is not greatly in excess of the thickness of the formation. The greater resistance to erosion, as compared with the overlying limestones, is responsible for the beds cropping out at higher levels than the limestones. In many places numerous blocks of Hardyston have moved down the slopes and now rest on the limestones considerable distances from the outcrop of the rock in place. Similarly the Hardyston outcrop is commonly concealed by the gneiss talus from the higher portions of the hills. A rule that in general is satisfactory is to draw the contact of the Hardyston and gneiss at or somewhat above the place where the last piece of the Hardyston is noted as one ascends the hill and to draw the Hardyston and Tomstown contact at or near the point where the slope of the hill changes or where sinks appear as one descends the hill. Since talus so generally conceals the outcrops these somewhat inexact methods must be used in mapping.

Normally, the Hardyston should crop out everywhere between the pre-Cambrian crystalline formations and the Tomstown but in several places no evidence of its existence can be found. In the absence of exposed sections from the gneiss to the limestone, it is necessary to choose between three explanations. (1) The formation is present but thoroughly concealed by talus and soil. (2) Faulting has occurred by which the gneiss and limestones have been brought into contact. (3) No deposit was formed at that particular place or it was entirely removed by erosion before the deposition of the Tomstown. Differences of opinion are bound to result and no one's work should, therefore, be discredited on that score. The present investigators have mapped the Hardyston only in those places where some positive evidence has been obtained. If the evidence is only that of loose fragments of rock in the surface soil, an uncertainty sometimes prevails in that the Hardyston presents a great variety of lithologic phases, some of which are indistinguishable from similar features of the Silurian and Devonian sandstone and quartzite boulders brought into the region by the glaciers during the Pleistocene period. In general, the glacial cobbles and boulders are more rounded or faceted but not in every case.

An instance of difference of opinion may be cited in the mapping

of the Hardyston. Prime[73] shows a band of Hardyston that includes nearly all of Fountain Hill and continues in an unbroken band along the north slope of South Mountain almost to Saucon Creek. At one time the senior author was inclined to accept part of this mapping but further investigation leads him to believe that there is no evidence for its existence and that the formation is probably absent here. Prime even describes the occurrences as follows:

> At South Bethlehem a change occurs in the nature of the rock, and in place of the quartzite we find a *red shale* occurring in the street close to and west of Dr. Lindermann's residence. At first sight this shale presents an appearance very much like that of the New Red Sandstone, but its location and stratigraphical position show that it must be of Potsdam age. The change in the lithological character of the rock is probably due either to the original shore-line having been very flat and thus given rise, locally to the deposition of silt; or else, to a stream having poured into the Silurian sea at this point during the Potsdam epoch.
>
> In the rear of Lehigh University the sandstone is seen of the normal type, as well as at other points along this ridge of the South Mountains. It continues to a point a little east of the North Pennsylvania (Reading) railroad and may be seen in the railroad cut, having a northwest dip and *non-conformable* with the underlying syenitic rocks which dip to the southeast. (p. 207.)

It is puzzling to know what Dr. Prime saw that can not now be seen. One wonders whether the "red shale" was not a weathered exposure of a Tomstown shaly bed and whether the "normal type" of sandstone was not an acid phase of the Byram gneiss. If the Hardyston is present as mapped by Prime, the outcrop should be in the lower part of the Lehigh University campus but no excavations for new buildings during the past thirty years have passed through the hillside talus and to the writer's knowledge no fragments of undoubted Hardyston were found. He still hopes that at some time some excavation at a critical point will definitely settle the question. It is present and was quarried a short distance west of the road crossing the east end of the mountain and was at one time exposed in a shallow roadside cut near the crossing of Saucon Creek by the Bethlehem-Hellertown road. These two outcrops have been connected on the map although it is by no means certain that they should be.

Altogether, it is to be expected that any future worker who remaps the area will make numerous changes, but it is believed that they will be of minor importance. However, if it be assumed that the ferruginous chert and jasper, which the writers believe to be part of the Hardyston formation, "was produced by silicification of the limestone and is evidence of the presence of limestone" as held by Stose and Jonas[74] any remapping will present many drastic changes. This question is discussed on a later page.

[73] Prime, F., op. cit.

[74] Stose, G. W., and Jonas, A. I., Geol. Soc. Am. Bull., vol. 46, p. 773, 1935.

Lithologic characteristics.—The Hardyston in Northampton County presents more varied lithologic features than any of the other sedimentary formations. This variability occurs not only in the vertical range of the beds but also along the strike and in very short distances. In many cases certain of these characteristics are peculiar to only one or a few local outcrops.

From an early date, when the formation was designated as the Potsdam, to the present, it has been more or less customary to speak of the whole formation as Hardyston (Potsdam) quartzite. Such a designation is distinctly inaccurate since we have learned that true quartzite constitutes only a minor part of the formation. Instead, it contains conglomerates, sandstones, quartzites, jasper, chert, shales and locally a micaceous material that has been called pinite.

Conglomerates.—At or near the base of the Hardyston formation there is often a coarse conglomerate. It is composed of well-rounded quartz pebbles, often lightly stained to a wine-red color. These pebbles are cemented in a dark quartzose matrix. This matrix contains some epidote, chlorite and detrital heavy minerals. The size of the quartz pebbles ranges from one-quarter inch to four inches in diameter, even the largest being well rounded. The color of the matrix varies somewhat, but usually it is dark. At no exposure in Northampton County does the thickness of this member exceed eight to ten feet.

Although the conglomerate occurs often as float, there are only a few places in the counties where good exposures occur. At the east end of Morgan Hill, south of Easton, a good outcrop shows the relation of the conglomerate to the underlying gneiss. A few inches of mashed gneissic material intervenes between the gneiss and the conglomerate, which is itself only a foot or two thick. The conglomerate is overlain by a gray pyritic schistose bed. The latter has acted as an incompetent member, and it shows fine fracture cleavage. The occurrence of the conglomerate is irregular here, even within a few feet. For this reason, and because the schistose material above the conglomerate shows that there has been movement, it appears that a bedding plane fault within the Hardyston has displaced some of the conglomerate, leaving only a few inches of it on the gneiss.

Quartzite and sandstone.—The sandstones and quartzites are not discussed separately as they grade into each other so thoroughly that no sharp distinction can be made. Following the custom previously mentioned, here all are called "quartzite." There are two common varieties,—the arkosic and the non-arkosic.

The non-arkosic is less abundant. In a hand specimen it is commonly bluish gray, gray or white whereas the arkosic varieties are

generally buff or salmon-colored. Most of the occurrences show a fine-grained, fairly homogenous rock that breaks readily under the blow of the hammer, almost like glass, and produces conchoidal fractures. Pebbles or sand grains are not readily observable by the naked eye.

Under the microscope in thin section the rock is seen to be composed of a mosaic of interlocking quartz grains which reveal secondary enlargement of rounded quartz particles. Impurities, such as iron oxide, are confined chiefly to the present grain boundaries although in some cases they surround the original sand grains.

The most typical phase of the Hardyston formation is an arkosic quartzite. This rock is buff, salmon-colored, or white, depending upon the amount and condition of the feldspar, or arkose. Blue and gray rounded quartz grains make up most of the rock. In the typical building stone variety of arkosic quartzite the quartz grains are between one and three millimeters in diameter, but a pleasing irregularity is caused by scattered larger grains, seldom larger than one centimeter. The feldspar often is quite fresh, but more generally is altered to kaolin or sericite. The fracture of the rock is rough, giving it a massive appearance which further adds to its attractiveness as a building stone.

The arkosic quartzite beds of the Hardyston, where exposed, usually run from the basal phase to the erosion surface. This fact is easily accounted for when one considers that nearly all the exposures are in quarries, and that these openings would naturally start where good building stone cropped out, and extend as deep as there was workable stone, which would usually end at the top of the basal phase. At no place has the author seen an upper contact of the arkosic quartzite. It may grade into the limestones, but the upper contact apparently is covered with talus and soil, so that the sequence is unknown to the writer. For the same reason the thickness of the phase can only be estimated. In various quarries the thickness of the exposed arkosic quartzite is up to 60 or 75 feet. The total thickness of the phase may be 125 feet in places.

The arkosic quartzite in thin section shows the chief mineral to be quartz. Most of the quartz grains are less rounded than in the true quartzite. The presence of arkosic material suggests that at least some of the quartz must have had little chance to become well rounded. Some secondary enlargement of the quartz grains has occurred, but there is also much sericitization in the binding material. The feldspars are remarkably fresh in thin section, being mainly microcline, soda microcline, and microperthite. These minerals show some alteration to sericite. Euhedral grains of pyrite are disseminated through

most specimens of the rock. A few grains of zircon are scattered through the sericitic matrix.

In a cross-bedded quartzite from a stream bed northwest of Redington the lines of black material that bring out the effect of cross-bedding are merely areas where magnetite was concentrated. This magnetite has been altered somewhat to hematite and limonite, but it still retains its bluish luster in reflected light. The cross-bedding, the freshness of the feldspar, and the presence of magnetite all indicate that the rock was deposited in shallow water by streams with fairly rapid flow. The minerals are typical of the disintegration of the Byram gneiss, in which even magnetite is present locally in rather large amounts.

The arkosic quartzite that contains the *Scolithus linearis* horizon appears to be the same as the ordinary rock in respect to mineral content and microscopic appearance. The grains of opaque minerals are more numerous in the tubes than in the host rock, or vice versa. No other unusual microscopic characteristic is present.

Jasper.—Throughout Lehigh and Northampton Counties the Hardyston formation has local occurrences of jasper. Although the jasper is generally found as float, there is at least one locality, west of the Allentown-Philadelphia highway, south of Mountainville, Lehigh County, where it crops out as massive beds in the stratigraphic position of the Hardyston.

The jasper of the Hardyston is taffy yellow to dark brown, or red. It is fine-grained, having a satin-like surface when very fine, and a fine sandy surface when coarse. The fracture varies from perfect conchoidal to rough. The rock is often a breccia which has been re-cemented by silica in the forms of chalcedony and quartz.

The jasper does not seem to occur at any definite horizon in the Hardyston, nor is it usually persistent for any great distance along the strike. One fact is generally true, namely, that the jasper phase is closely associated with the iron-ore phase. In nearly every old iron mine there are many blocks of jasper. The limonitic iron ore must be closely related to the jaspers in origin.

At several localities in Bucks and Lehigh Counties, jasper pits were worked by the Indians, who there obtained their stone for weapons and implements. At Vera Cruz rather extensive openings were made. Large amounts of jasper chips are lying in the fields nearby, but no actual arrowheads or implements have been found. Presumably the Indians roughed out their weapons here, to make transportation easier. The fine dense jasper probably was very much sought for by the Indians, and the pits probably were carefully guarded by the tribes.

Myers[75] and Fraser[76] have made detailed microscopic examination of the jaspers of the region. The following paragraphs are quoted from Fraser's article:

That the Hardyston has been altered to jasper or ferruginous chert in many places has been contended by B. L. Miller, who for many years has been guided in part by these materials in tracing the Hardyston in the area. P. B. Myers' study of the Hardyston quartzite in Lehigh and Northampton counties also showed the close association in the field between the jasper and the quartzite. He found and described arkosic facies of the Hardyston showing silicification in the form of encroachment of small microcrystalline areas of silica into both quartz and feldspar grains in the quartzite.

An especially good example of the formation of jasper and ferruginous chert by the complete replacement or reorganization of Hardyston quartzite was found by Robert D. Butler and the writer one and three-quarter miles north of Limeport in the southwest part of the Allentown quadrangle. Small indistinct rounded patches on the surface indicate the former sand grain areas and show definitely that here is a piece of Hardyston quartzite which has been jasperized.

The true nature of this alteration is well shown in thin-section. The rounded grains of the material appear as grains of quartz in the thin-sections. They are typically rounded sand grains firmly cemented together to form a dense quartzite. The cementing material contains small amounts of sericite and (or) chlorite and iron hydroxide granules. In plane polarized light the material appears to be a normal quartzite but when the nicols are crossed the true cherty or jaspery nature of the mass is immediately apparent. The supposed large rounded quartz grains are made up of hundreds of minute granules of silica, the typical crypto- or microcrystalline silica of a silicified rock.

The minute granular nature cannot be related to crushing because the rounded outlines of the larger grain-areas would have been distorted. The suggestion that the original sand grains may have been chert particles is disproved by the close relationship between the small silica granules of the grain areas and those of the matrix or cementing material. Those of the latter area are somewhat larger in places and this feature together with the greater abundance of iron hydroxide in the cementing material serves to outline the sand grain areas both in plane polarized light and between crossed nicols. The fact that some of the thin-sections show a gradation into ordinary ferruginous chert completely lacking in sand grain structure also indicates a later replacement origin rather than a primary deposition of the rounded grains as chert particles. It is thought therefore that there is little doubt that the origin must be one of complete replacement or at least reorganization of the original siliceous rock by iron-bearing siliceous waters.

In many places in the field large amounts of massive jasper or ferruginous chert associated with the Hardyston, bear no trace of the former sandstone structure of the original formation. These areas illustrate the gross replacement wherein masses of the Hardyston were replaced by colloidal silica which later crystallized. Another type of replacement is that wherein the process occurs on a more minute scale in which original structures are preserved. Here, too, the secondary silica is probably deposited in colloidal form, producing a gel which later crystallizes. It is this latter type of jasper or ferruginous chert which is of special importance in the conclusions listed below.

1. Silica-bearing waters have widely permeated the lower Paleozoic sandstone and limestone of the eastern Pennsylvania Highlands.

[75] Myers, P. B., The Origin of Jaspers in Lehigh and Northampton Counties, Pennsylvania: Pa. Acad. Sci. Proc., vol. 8, pp. 87-92, 1934.

[76] Fraser, D. M., Replacement of Hardyston Quartzite by Jasper: Pa. Acad. Sci. Proc., vol. 11, pp. 57-61, 1937.

2. Chert and jasper have been formed in places by the replacement of limestone by the silica in these waters.

3. Jasper and ferruginous chert have been formed in many places by the replacement of the Hardyston quartzite by these waters.

4. The mapping of areas wherein jasper and ferruginous chert are found might be carried out on the basis of the following suggestions:

   a. In known limestone areas the presence of jasper and ferruginous chert may be considered as having been formed by replacement of the limestone.

   b. Where the areas of these materials are in structural continuity with the Hardyston, are found together with the Hardyston, or are on the higher slopes or tops of pre-Cambrian hills they should be considered as having been formed by replacement of the Hardyston.

Shales.—In scores of places limonite iron ore has been mined in the past from the Hardyston, as will be described in a later chapter. The ore was generally found in a matrix of yellow, red, white or black clay. An examination of numerous old mine dumps reveals many angular blocks of jasper, ferruginous chert and occasional sandstones. The occurrence leads to the conclusion that the ore bodies lie within this formation and it, therefore, is necessary to account for the origin of the clay. The siliceous types of rocks described above can not have been the source of the clay so it seems necessary to assume that the Hardyston contains much shale, especially in the upper portion, although the writers have never seen any development of shale in the formation in this region such as must have been present to explain the large deposits of clay. An exposure of calcareous shale near the top of the formation is reported in the bed of a brook near the old Thatcher Mine east of Stewartsville, N. J., only a few miles east of the Northampton County line. So far as known, no mine workings were ever deep enough to locate shale, although some were over 200 feet in depth. With the known facts, we reach the conclusion that shale masses occur within the Hardyston at different horizons from the base to the top, since ore in clay occurs at these different places, and that these shale bodies were lenticular, extending to variable distances along the strike, and absent in many places.

Since the overlying Tomstown contains numerous shale beds or lenses and its contact with the Hardyston is everywhere concealed where ores have been mined, it has appealed to some people to assign all the "mountain ore" limonite bodies to the Tomstown. The association with undoubted Hardyston and the characteristics of the ore do not seem to support this view, although it may well be that in some cases the mines shown on the map as included in the Hardyston may more properly be assigned to the Tomstown.

Pinite.—In several localities, many more in Lehigh than in Northampton County, a peculiar soft, dense, light-green rock is present

which is structureless to the naked eye and has been designated as pinite. It occurs only at the base of the Hardyston. Under the microscope it is found to be composed mainly of sericite mica but with smaller amounts of quartz, epidote and chlorite. In a few places it has been colored red by iron oxide. Fragments of quartz and a lamination parallel to the contact with the surface of the underlying gneiss are occasionally noted, both of which were probably developed by slipping during periods of folding. Rarely the pinite contains some rounded water-worn pebbles. This type of rock has not been seen at any other horizon. It is believed to have been made by the metamorphism of an old residual gneiss soil that was formed before the deposition of the Hardyston and not destroyed by the waves of the advancing sea at the time of submergence of the region in Lower Cambrian time.

Paleontologic characteristics.—The arkosic quartzitic phase contains the only fossil record yet described in the Hardyston of eastern Pennsylvania. *Olenellus* has been found in the New Jersey Hardyston, but thus far no trilobites have been discovered locally. The only feature that may be ascribed to marine life is *Scolithus linearis,* or "worm borings." Throughout a thickness of a few feet, and occurring rather widely as a distinct layer, there is a quartzite which contains long narrow cylinders, filled with material of a different color from that of the bed. Some of these tubes are a foot in length. They range in width from about one-eighth to half an inch. There seem to be two distinct sizes, of the dimensions just mentioned. They were recognized by the first geologists of the region as distinctive of the Hardyston (Potsdam of that time) formation. The tremendous number of tubes makes it a bit difficult to believe that they could have been formed by worms and then be filled uniformly with a different colored sand. However, the worm burrow theory is the only one that seems at all plausible.

Thickness.—The thickness of the Hardyston is extremely variable. East of Freemansburg it is apparently not more than 25 feet. This suggests the explanation of its absence between the gneiss and the Tomstown in some places as due to non-deposition. In other localities in the county the Hardyston appears to be as much as 200 feet thick. A short distance east of the Delaware River, two miles south of New Village, sandy and calcareous shales referred to the formation give a total thickness of 325 feet. To the southwest, through Lehigh and Berks Counties, the formation thickens to more than 400 feet. The lack of exposures at the top of the formation prevents exact determinations of thickness.

Name and correlation.—In the Second Annual Report of Rogers in

1838, he described the Hardyston as his Formation No. 1 of his Secondary rocks. Later he designated it as the Primal White Sandstone and correlated it with the Potsdam Sandstone of New York. While Prime was investigating the geology of the Lehigh Valley for the Second Geological Survey, the name Potsdam was continued. When later several paleontologists and stratigraphers proved conclusively that the Potsdam of New York is Upper Cambrian in age and is underlain by a great thickness of limestones, shales and quartzites of Paleozoic age it became apparent that the Pennsylvania and New Jersey basal Cambrian siliceous deposits should not be correlated with the Potsdam of New York but rather with the Poughquag quartzite of the Taconian (Georgian) series.

Wolff and Brooks[77] proposed the name Hardistonville in 1897, from Hardistonville, N. J. This name was slightly modified by Kümmel and Weller[78] who proposed the shorter township name of Hardiston (later changed to Hardyston) which has since been widely adopted. Even yet, however, one finds the occasional use of the name Potsdam.

The Hardyston of Northampton County is correlated with the Chickies formation of Chester and Lancaster counties, and with the Antietam sandstone of Franklin County, Pennsylvania.

Stratigraphic relations.—The Hardyston rests unconformably upon the older pre-Cambrian crystalline gneisses. Some of the earlier workers confused banding of the gneisses with bedding planes and announced the conformability of the two classes of rock. It is evident that there was a long interval of erosion between the deposition of the basal Hardyston and the solidification of the underlying igneous rocks.

Presumably, the Hardyston is overlain conformably by the Tomstown formation although no exposure of that contact is known within either Northampton or Lehigh County. Where strata of the two formations are seen in proximity, the close parallelism of strike and outcrop suggest conformability.

Local details.—At Camels Hump three miles north of Bethlehem, the Hardyston formation is a rather narrow band on the south slope of the hill formed by pre-Cambrian gneiss. This band extends on the east to the northeast end of the hill, following the contour of the steeper slope. East of the road intersection at the southwest corner of the hill there are several old shafts from which umber was taken. This umber, and along with it some less manganiferous limonites and iron-rich jaspers, is good evidence for the presence of the Hardyston.

[77] Wolff, J. E., and Brooks, A. H., Age of the Franklin White Limestone of Sussex County: U. S. Geol. Survey, 18th Ann. Rept., pt. II, pp. 431-457, 1898.
[78] Kümmel, H. B., and Weller, Stuart, Paleozoic Limestones of the Kittatinny Valley, New Jersey: Geol. Soc. Am. Bull., vol. 12, pp. 147-161, 1901.

Also there is an abundance of the gray and buff arkosic Hardyston of rather coarser than medium texture.

On the north side of the mountain east of Freemansburg, the evidence for a mile and a quarter east of the road across from Freemansburg is very scanty. Several pieces of Hardyston have been picked up at different times along the hill slope. The writer found two pieces of rather pebbly rock near the built-up part of the town. Other than this, nothing was found west of the outcrop of gneiss at the point where the river swings close to the mountain. Earlier workers[79] found enough Hardyston to convince them that the formation is present.

At the point where the road leads uphill, 1¼ miles east of Freemansburg, the gneiss is exposed along the road. Just beyond this nose the Hardyston is exposed well up on the face of an old quarry. The strike of the bed and its position south of the point where the gneiss crops out indicate a fault. Limestone is exposed on the east end of the quarry. The Hardyston is probably about fifty feet thick, with the most abundant material a gray sericitic rock containing a few rounded, scattered grains of clear quartz. It is possible to trace this band of Hardyston, by its float, eastward for some hundreds of feet, beyond which only occasional fragments are found and still further east all evidence of its presence disappears. Evidently there is an east-southeast fault which Bull Run follows. Then there is probably a north-northeast fault which has brought about the presence of limestone and gneiss almost on opposite sides of the road. This latter fault is also indicated by the apparent termination of a band of Hardyston one mile southeast of Redington.

Evidence for Hardyston is revealed in the gully just east of, and parallel to, the road southeast of Redington. In this dry creek bed there are many large blocks of a gray to gray and black rock which are undoubtedly Hardyston, as well as pieces of yellow jasper.

The next real indication of Hardyston is along the road at the hill two miles east of Redington. Here several large blocks of drusy jasper occur along the road. There are some pieces of jasper in the ravine north of the road, too. This jasper is similar to that found in the Hardyston at Vera Cruz in Lehigh County.

The Hardyston along the mountain southeast of Island Park strikes about parallel to the road at the upper limit of the cultivated fields. Much mining has been done along this band of Hardyston, most of it underground work. The typical Hardyston is a gray arkosic rock, with some quartz pebbles. Pebbly Hardyston is also present around the mines. At the valley half a mile west of Fairview School, the Hardyston seems to be a quarter of a mile south of the road, as is

[79] Rosalsky, M., and Buie, B. F., personal communication.

indicated by old mine workings in the valley. The formation does not continue eastward at this point, but east of the valley is displaced about one-eighth mile northward, as shown by the iron mine near the road and by the presence of Hardyston on the hill above the road one-quarter mile northwest of Fairview School. Two iron mines here, with some jasper and siliceous rock, indicate Hardyston. East of the next road, the Hardyston is marked by iron mines eastward to the transmission line. Here the band is about one-quarter mile north of Fairview School. Some gray arkosic quartz rock found here indicates certain Hardyston.

At the transmission line there is an abrupt change. No more mines are found immediately east of the line. The only evidence for Hardyston consists of a few pieces of dubious material, with angular and subangular pieces of quartz cemented loosely by an arkosic ferruginous cement. It does not look like typical Hardyston, nor does it look like any of the gneisses that have been found anywhere in the region. This rock is more prominent as one goes up the little valley east of the transmission line, until, near the farmhouse at the north end of the lane indicated on the map, there is some pebbly rock which seems to be a true Hardyston type. Some more rock, which is apparently Hardyston, occurs in large blocks in the fields just east of the lane. The gneiss-Hardyston contact is between 660- and 680-foot contours circling the nose east of the lane. The Hardyston is plentiful west of the valley that marks the eastern side of the nose. Some white chert was seen here, as was also the odd pebbly arkosic rock. On the east side of this valley only gneiss is evident above the 560-foot contour. This and the apparent jump of the contact at the transmission line on the west side of the nose indicate a pair of faults between which the block represented by the nose has been raised. The Hardyston on the nose would then represent a thin remnant which lies on the hill as a dip slope.

Some pebbly rock and some jasperoid material occur up to about the 560-foot contour along the south side of Morgan Valley. The presence of this Hardyston is further indicated by the abandoned workings of an iron mine a few hundred feet southwest of the oldest and highest farmhouse on the south slope of the valley.

This Hardyston in the eastern part of Morgan Valley is probably the end of a canoe-shaped syncline. The presence of an iron mine at the 600-foot contour in the east end of the valley shows that the Hardyston circles around the basin. There is some pebbly Hardyston above the mine, extending possibly to the 620- or 640-foot contour. The geology of Morgan Valley is extremely complicated. The topog-

raphy and the Hardyston outcrops as shown on the map seem to be in agreement.

Undoubtedly one of the most interesting exposures of the Hardyston in Northampton County is that on the eastern extremity of Morgan Hill, just west of the highway along Delaware River. Here an old electric railway cut exposes the gneiss-Hardyston contact for several hundred feet, besides which there are two other definite outcrops higher up on the north side of the nose.

The most characteristic Hardyston at the locality is an arkosic basal conglomerate, with quartz pebbles up to one and one-half inches in diameter. These pebbles are fairly well rounded. The matrix is arkosic, but is rather altered, apparently to sericite and epidote. This basal conglomerate, resting on the gneiss with a rather sharp contact, is striking. A few inches of mashed gneissic material overlies the gneiss, and above the mashed zone there is a varying thickness of conglomerate. The conglomerate was not observed to be more than two feet thick at any point and at a few places is absent. Pegmatites have been found here.

The rock overlying the conglomerate is a medium-textured sericitic or mashed rock, carrying a conspicuous amount of pyrite. It is generally a light gray rock, but where shearing has been more intense, it is greenish. This material apparently lies in contact with the gneiss where the conglomerate is absent. At the highest outcrop on the north side of the nose in the bend of Delaware River, the thickness of this member is about four feet. Here, however, the top is the erosional surface, so the thickness may not mean much.

All the material shows distinct evidence of movement and shearing. Gash veins and what is practically flow cleavage are present in the upper member, which was the incompetent one. Both of these indicate that the upper beds moved down the dip. This, coupled with the fact that the presence of the conglomerate is so local, may indicate that the main body of the Hardyston was here downfaulted, the fault locally taking place within the formation, leaving five or ten feet at present as a thin veneer on the gneiss.

The strike at the largest exposure of the bedding plane in the railroad cut is N. 72° E. with a dip 43° NW. At the outcrop 100 feet west of the highway at the old railway crossing the strike is N. 35° E., with a dip of 60° NW. West of this point, high on the hill, the strike is N. 32° E., the dip 55° NW.

Following westward along the strike of this last outcrop, there are only a few scattered pieces of Hardyston to where a lane makes an abrupt turn up the hill. In the fence in front of the house at this

point, and in adjacent fields, there are several blocks of arkosic buff Hardyston.

Some of the Hardyston along here is an arkosic rock showing alteration. Westward along the road a few pieces of both the buff and the very arkosic Hardyston can be found. The contact seems to be south of the road, but not far from it.

The next gully to the west is a good place to look for the gneiss-Hardyston contact. Here the gray sericitic rock is a bit higher on the hill. Just west of this gully there is an abandoned iron mine in the Hardyston. The south wall of the mine is a gray pebbly rock striking N. 65° E. and dipping 75° NW. The iron ore was taken out for several hundred feet, but the opening was comparatively narrow. Across the road to the northwest there is another small mine.

Just west of these two iron mines there is another ravine or gully that is quite swampy with springs. This might be an indication of a north-south fault at this point. It is interesting to note that although there are many iron mines west of this point, the writer did not see any pebbly or arkosic Hardyston. The only evidence for Hardyston is the brown jasper associated with the iron ores.

Half a mile east of the road which leads over Morgan Hill there is a lane leading up the hill to the southeast. Jaspery rock occurs in the gutter for 100 yards. There is also a pebbly rock with rather angular grains of quartz, which may be Hardyston, but which also resembles a rotten gneiss. About halfway between this lane and the east-west road along the north base of Morgan Hill, there is a small pit that may have been an iron mine. Some pieces of jaspery iron ore are lying around. The fields just west of this hole contain more small pieces of coarse jasper. Residents say that there were some mines between this point and the Morgan Hill road but they are obliterated now.

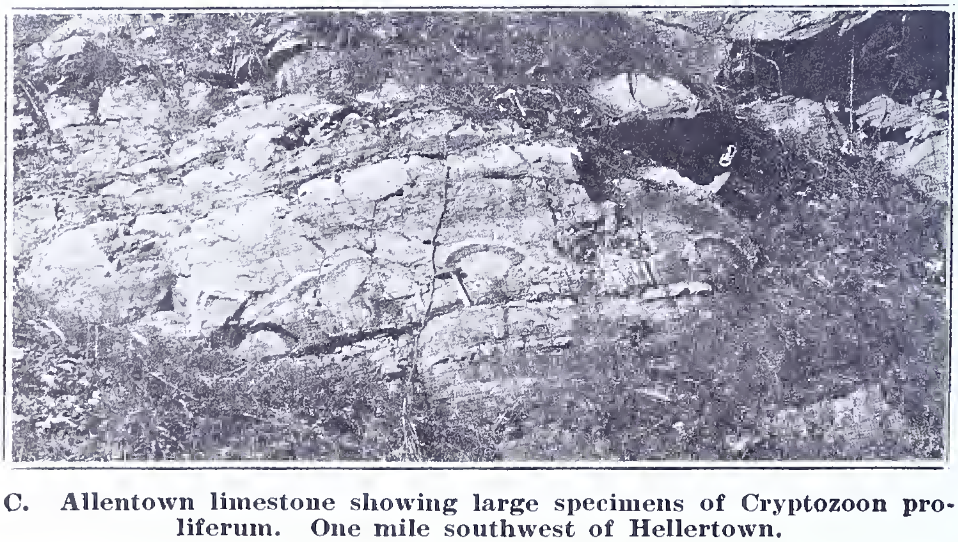
From the Morgan Hill road westward to about half a mile east-southeast of Glendon, there is a practically continuous group of abandoned workings, formerly large open pits and shafts. Some of the pits are partly filled with water and some have been filled with refuse. Numerous pieces of ore and associated rock are scattered around. Near the first pit west of the Morgan Hill road there is a pile of ore that accumulated when the mine was last worked for umber. Specimens showing replacement can be found here. Some of the pieces seem to show a replacement of limestone.

The longest continuous belt of the Hardyston formation in Northampton County is that which starts at the county line at Spring Valley and runs continuously to Coffeetown on the Delaware. The eastern end of the belt is not definitely known at the moment, but the Hardys-

PLATE 12.

A. Hardyston sandstone in Deemer quarry near Lost Cave, Hellertown.

B. Detail of structure in Deemer quarry.



C. Allentown limestone showing large specimens of Cryptozoon proliferum. One mile southwest of Hellertown.

ton surely comes very close to Coffeetown. The belt is at least nine miles long.

At Spring Valley the evidence for Hardyston is rather poor. The chief reason for extending the Hardyston to the county line is a large outcrop of that rock about one-quarter mile east of Spring Valley. The outcrop is just west of a tributary of Saucon Creek. The rock is a crushed and fractured arkosic quartzite, having strong local resemblance to gneiss. Fracturing and jointing obscure the true attitude of the beds. Further work may clear up this difficulty. Just north of the outcrop, still on the west side of the creek, there are numerous large slabs of a grayish-buff arkosic rock, carrying some pebbles of quartz. This rock is not like that of the outcrop, but it seems to correspond to some of the arkosic Hardyston elsewhere in the county. There are many springs and much swampy ground up the hill to the east. The evidence for Hardyston is almost nil eastward on the spur at Saucona. Abundant glacial debris and Triassic float may mask the Hardyston. One or two pieces of coarse jasper may indicate its presence.

Down the slope east of Saucona there is an abundance of jasper and chert. This float, in pieces up to a foot and a half in one dimension, is present all along the valley southward towards Leithsville. The northern boundary, or the contact with the limestone, is not definite, but on the basis of float it is placed as crossing the road six-tenths mile east of the crossroads at Bingen. The contact runs northeast from this point.

It must be admitted that the evidence for Hardyston on the north side of the hill near Saucona and for a considerable distance west, north and northeast of Leithsville is very scanty. Blocks of jasper, chert and arkosic sandstones occur but are not sufficiently numerous to satisfy the writer in the mapping which he proposes. It is probably the simplest way of mapping an area where much Triassic float has covered the surface.

Where the Bucks County line crosses a road junction in the center of the valley about a mile and a half east of Leithsville there are great chunks of jasper and quartzite. Some of the jasper resembles that at Vera Cruz, with drusy quartz crystals encrusting it. One may find many pieces of jasper westward along the road and along the creek.

Near the Hellertown Water Works southeast of Hellertown in the valley of Poke Valley Run, there is some quartzite that is a bit different than much of the Hardyston found elsewhere in the county. It is a brittle gray quartzite with pebbles up to three-eighths of an inch in diameter. These pebbles are clear bluish quartz, very solidly

cemented together by clear quartz. The fresh chips have a very glassy appearance. The type is apparently local, being confined to an area west of the water works.

East of the water works, the Hardyston is traced by float through woods and field to the road that crosses the narrow valley. The Hardyston seems to be limited to the south side of the creek, with its base about 150 yards south of the creek. Near the head of Poke Valley Run there are several iron mines. The best outcrop and most typical conditions are in the most easterly one. The south wall is arkosic quartzite, rather fine-grained. It strikes N. 80° W. and dips 30° SW. The iron ore has formed at the base of the Hardyston; the north side of the mine is gneiss.

In the loop of Hardyston east of the lane half a mile southwest of Deemer School there is a quantity of jasper that has been cracked and filled several times. Some of the original cracks were too large to be filled. The appearance suggests tension cracks such as are caused in drying. This jasper is similar to that at Bowers, Lehigh County.

Where the transmission line crosses the head of Stouts Valley there is an abundance of Hardyston float. It is a coarse arkosic quartzite, locally showing the pebbly basal phase.

The valley of Silver Creek directly east of Hellertown presents some interesting geologic features. The Hardyston in it ranges from white chert to arkosic quartzite, locally rich in pyrite. Several iron mines were once worked in the valley. Faulting is indicated by the peculiar shape of a window of gneiss and by springs.

In the area east of Wassergass, the south contact with the gneiss is a normal one. The Hardyston is exposed as the footwall of the iron mine just south of the crossroads. The rock is an arkosic quartzite, quite rich in pyrite. It strikes N. 62° E. and dips 70° NW. From the footwall of the mine southward to the contact with the gneiss only about fifteen or twenty feet of quartzite intervene. Much loose jasper and limonite are lying about, indicating that the ore-bearing strata were more jasperoid than quartzitic. The only significance of this is that at this place the jasper-limonite phase is stratigraphically higher than the arkosic quartzite. The occurrence of pyrite in the quartzite may strengthen the theory that the limonite ores have been formed by the oxidation of pyrite and the subsequent concentration of the hydrous oxides of iron.

The flat-bottomed valley at the head of the East Branch of Saucon Creek has long been a puzzle. A previous map by the senior author shows it underlain by limestone. Recent more detailed investigations have revealed numerous blocks of Hardyston in different parts of the valley. There are no outcrops of rock in place. The topographic

appearance of the valley would suggest limestone but there is no evidence of its existence. It is recognized that there is a probability that both the Hardyston and Tomstown may be present.

The mapping of the Hardyston in the Seidersville area is rendered uncertain by the presence of large amounts of glacial debris. Boulders up to six or eight feet in one dimension have been dropped here by the ice. Mapping has been done on the basis of Hardyston float.

Hardyston certainly occurs on the south side of the valley one mile southwest of Seidersville. An iron mine is located in it. This mine, which seems to represent a series of prospects rather than an extensive mine, was in a white chert, which locally is stained pink. Hardyston float occurs for a short distance between the 440- and 480-foot contours on the road to the west. Scattered pieces of float occur in the partly built up area northwest of the road at this point. All this float is quartzite, some of it the typical arkosic variety.

Near the Lehigh County line southwest of Seidersville, the Hardyston is mainly a white chert locally stained pink. Some iron ore was mined in this type of rock and blocks of the typical arkosic quartzite are present.

Arkosic quartzite was quarried on a small scale behind a barn in Seidersville. This outcrop is near the contact with the gneiss. The contact crosses the Philadelphia pike and continues for about a mile east of Seidersville, where all the evidence for the Hardyston stops. Although it may be present farther east, it certainly does not appear in the float, which is nearly all gneiss. The gneiss certainly is in contact with the limestone at Saucon Park.

Tomstown Formation

Distribution.—Almost all exposures of the Tomstown formation within Northampton County are south of the Lehigh River. It appears in an almost continuous band along the south side of the river between Bethlehem and Easton. Also it forms the floor of a considerable part of the Saucon Valley and of valleys of several small streams tributary to Delaware River. North of the Lehigh River outcrops of Tomstown limestones are associated with the uplifts of Camels Hump and Chestnut Hill.

Good exposures of the Tomstown are not common because of the position of the outcropping near the base of the larger hills composed of pre-Cambrian gneiss. Hillside talus conceals the outcrops over extensive areas and to depths up to fifty feet or more. Residual soils and glacial and alluvial deposits also add to the surficial cover. For these reasons the formation lines as placed on the map are subject

to revision as erosion or artificial excavations result in further exposures.

Lithologic characteristics.—The Tomstown formation of the region is composed almost entirely of dolomitic limestones. Several types have been recognized. The most common is a thin-bedded, high magnesian, impure limestone with the individual beds less than one foot thick. This grades into a more argillaceous variety with an abundance of sericite, which produces a glistening silvery appearance on the bedding planes. In turn this passes into a true sericitic shale in which there are practically no carbonates. These shales have been noted in many places and may have a thickness up to ten feet although usually less than one foot. An especially thick band of Tomstown shale is exposed in an old limestone quarry along the Delaware River Road about three-fourths mile north of Raubsville. On Prime's "Geological and Topographical Map of a part of Northampton County" published in 1878 this occurrence is mapped as "Hudson River & Utica Slates," the Martinsburg of our present classification. All these thin-bedded varieties break into thin fragments on weathering and are conspicuous in the surface soil or sub-soil.

Another phase of the Tomstown is a massively bedded dense dolomitic limestone in which individual beds are upwards of ten feet thick. Some of the finer-grained dense layers break with a distinct conchoidal fracture. On weathering it breaks into thinner layers than may be observable in the fresh rock.

The variations of the Tomstown are frequent and abrupt both within the individual beds and from bed to bed. Nowhere has any guide stratum been observed that can be definitely recognized in other exposures. If the structures of the region were not so complex, it is possible that this situation might not be the case.

Almost everywhere in the region the Tomstown has been shattered by earth movements and the old fissures filled with quartz veins. Locally the dolomitic limestones may contain large numbers of fine quartz veins criss-crossing in an intricate manner. Well-developed quartz crystals have been seen in some of the open fissures. The beds have also been impregnated with silica from the circulation of heated solutions. Black flint is abundant in the Tomstown in places. The flint may occur in nodules or irregular masses that cut across the beds or in lenses following the bedding planes. The irregular masses are seldom more than six inches in diameter but may be several feet. The lenses may extend for six to eight feet. These flints have resisted erosion and consequently have accumulated in the residual soils in great abundance in many places. All these flints appear to be replacements of the dolomitic limestones by ground waters. In places tiny

angular quartz particles are distributed throughout the rock. Joint planes are abundant and in various directions so that it is difficult to obtain well-shaped blocks such as are desirable for building purposes. The bedding plane surfaces are generally rough or nodular.

Small, isolated, well-rounded grains of clear quartz are fairly common in the Tomstown limestones and are clearly seen on weathered surfaces. Rarely there are lenses of sandstone composed of similar grains in which the carbonates are almost entirely lacking. One of the thickest of these lenses noticed is exposed in the quarry at Redington formerly worked by the General Crushed Stone Co. It is ten inches thick and is overlaid by a gnarly siliceous dolomitic limestone. When fresh it is a compact dark bluish-gray rock which becomes iron stained on weathering and appears as a brownish sandstone. These sandy beds almost everywhere are prominently cross-bedded. A bed of gray calcareous sandstone, a few feet thick, in which grains of clear quartz have been cemented by calcium carbonate, is exposed just east of Lost Cave. Considerable pyrite is present. On weathering the calcium carbonate is removed and the pyrite oxidized to limonite, producing a porous ferruginous sandstone.

In color the Tomstown limestone ranges from a dark steel-blue to a dirty yellowish-white color. On weathering the stone becomes light buff to chalky white. Some of the carbonaceous and more highly argillaceous beds are almost black when fresh but these too, on weathering, become lighter in color, usually a dirty white.

Oolites, edgewise conglomerates, cross-bedding and ripple marks have been noted in various localities as local phenomena, and indicate the shallow water origin of the Tomstown. They are not distinctive features, as similar textures and structures occur in the other limestones of the county.

The distinguishing lithologic characteristics of the Tomstown are partly positive and partly negative. Small exposures or single specimens may not be sufficient to differentiate these strata definitely. Both the Allentown and Beekmantown may locally contain similar features to those just described. Where the exposures are more extensive, however, the thin beds of impure dolomitic limestones, the abundance of sericitic shales and the massive beds of dense dark blue dolomites are distinctive. Negatively the complete absence of *Cryptozoa,* so far as known at present, serves to separate the Tomstown from the Allentown. This criterion by itself should not be over-emphasized since it is recognized that elsewhere in the country strata both older and younger do contain these calcareous algae.

Chemical composition.—The Tomstown limestones everywhere in the county are high in magnesia. No low-magnesian beds have been

noted and very few with less than 18 percent $MgCO_3$. They are likewise almost universally high in their silica content, although some quarries worked for flux have yielded stone with less than 2 percent SiO_2. The Tomstown magnesian limestones probably will average more than 8 percent SiO_2 and considerable search must be made to find quarryable stone low enough in silica to be desirable as furnace flux. This has been an unfortunate situation since several of the iron furnaces of the past were built in close proximity to Tomstown outcrops.

The Thomas Iron Company long worked some Tomstown limestones near Island Park for flux. These were unusually low in silica in comparison with the normal amounts. The average of 23 samples analyzed by the company was 3.36 percent SiO_2, ranging from 1.62 to 8.46.

*Analyses of Tomstown magnesian limestones**

	1	2	3
CaO	29.21	29.92	31.95
MgO	20.61	19.73	18.05
Al_2O_3, Fe_2O_3	0.58	2.20	2.62
SiO_2	1.90	4.77	2.70
S	0.020		
P	0.006		
$CaCO_3$	52.16	53.43	57.05
$MgCO_3$	43.28	41.43	37.90

1. Quarry on south side of Lehigh River, opposite Island Park. Average of 108 cars shipped to Thomas Iron Co.'s furnaces. Analyses by Thomas Iron Co.
2. Redington quarry of Bethlehem Steel Co. Average analysis of stone quarried during 1916. Analyses by Bethlehem Steel Co.
3. O. E. Leh quarry, Redington. Analysis by Bethlehem Steel Co.

Thickness.—The complicated structures and the limited exposures thus far make it impossible to obtain any satisfactory measurements of thickness. At no place is the entire thickness exposed and in very few localities is there a contact exposed either with the underlying Hardyston or the overlying Allentown. Along the Delaware River Road at the northeast end of Morgan Hill it was possible to measure 600 feet of Tomstown strata but this does not seem to be the normal thickness. Farther west the formation appears to be considerably thicker, and reaches a thickness of 900 to 1,000 feet. Unfortunately, there is no section exposed that permits exact determination of thickness.

Name and correlation.—Until the writer and his colleagues began their investigations in the region in 1907, no attempt had been made to subdivide the limestones between the Cambrian quartzitic sandstones and the Ordovician cement limestones. They were grouped

*Other analyses are given in the chapter on Economic Geology.

under the name Kittatinny limestone, a term first used by the geologists of the New Jersey Geological Survey. In view of the uncertainty of exact correlation with other named formations, it seemed preferable to employ tentative local names and in 1909 Wherry[80] proposed the name Leithsville for this assemblage of rocks. The name is that of the small village in the south corner of Northampton County. This usage was followed in several publications. Later work, however, has seemed to indicate its correspondence with the Tomstown formation of the Chambersburg region and therefore that name is now substituted for the previously-used local term. The correlation is based on equivalent position with reference to underlying and overlying strata and on lithologic resemblances. The absence of fossils renders the correlation much less satisfactory than desired. It has been suggested that the upper portion of the formation be differentiated and mapped as the Elbrook but it is the present opinion of the writer that with existing information this is not feasible, although it is probable that some of the upper beds of the Tomstown of this region represent the Elbrook of the southern portion of the State.

The name Tomstown was proposed by Stose,[81] from Tomstown, Franklin County, Pa. Fossils found there indicate a Lower Cambrian age.

Stratigraphic relations.—The contact between the Hardyston and the Tomstown has not been seen anywhere in the region as it is so thoroughly concealed at the surface by hillside wash and surficial soil. The facts at hand seem to indicate that the two formations are conformable and that there is a series of shales transitional between them. The limonitic iron ores, once so extensively worked along the slopes of the gneiss hills, appear to have been largely developed in this transitional zone.

In few places have contacts of the Tomstown and the overlying Allentown limestones been observed. They appear to be perfectly conformable although the former is regarded as Lower and the latter as Upper Cambrian with no indication of a Middle Cambrian such as has been noted elsewhere in the Appalachian region.

Local details.—The best exposures of the Tomstown formation in Northampton County are in the limestone quarries. Besides localities previously mentioned, the following furnish typical characteristics.

Along the Lehigh Valley R. R. just west of the Bethlehem Union Station, shaly sericite beds alternate with dolomitic strata. Edgewise conglomerate is developed in several places. There is also at this

[80] Wherry, E. T., Science, new series, vol. 30, p. 416, 1909.
[81] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), 1909.

point a small cave that is believed to extend under a considerable portion of Fountain Hill although in recent years it has not been possible for a person to proceed more than fifteen to twenty feet from the entrance.

The Tomstown limestone crops out in several places in the east part of the grounds of the Bethlehem Steel Co. where thick and thin shaly beds alternate with massive dolomite. Black flint is prominent in the dolomite. Much of the shale has decomposed to such an extent that it can be dug readily with a shovel. The strata have been folded to such an extent that dips and strikes vary.

Along the Lehigh Valley R. R. directly east of Freemansburg some stylolites with points up to one and one-quarter inches in length have developed in Tomstown dolomites. Veins of quartz and calcite are numerous. In the section of the Tomstown on the left bank of the Lehigh River at Freemansburg and in several other places between Freemansburg and Easton on the other side of the river, occasional beds of dolomite have numerous small elliptical patches of white crystalline calcite or dolomite. These eye-like particles average about a quarter of an inch long. The weathered surface presents a pock-marked appearance. The fresh fractures are gray, speckled with the calcite ''eyes.'' We have called this variety ''bird's-eye'' limestone. Two quarries about half a mile to the east have been worked for massive dolomitic limestones for the manufacture of lime.

A few quarries were once operated in the vicinity of Redington and here can now be seen the best exposures of the Tomstown in the county. In a large quarry once worked by the General Crushed Stone Co. there is a sandstone bed about ten inches thick that has weathered to a brown color. It is underlain by about one foot of shaly rock and overlain by a bed of gnarly siliceous dolomite. Encrustations of ferrous sulphate indicate the former presence of pyrite, as does the brown color of the sandstone. A short distance away is the quarry long worked by the Bethlehem Steel Co. and later used as proving grounds in testing field guns. Considerable shaly rock is present. A rather large cave here at one time contained some excellent stalactites and stalagmites. Black flint nodules are present in the dolomitic limestones of the Redington district and also quartz veins, stylolites, numerous joints, and small faults.

At the Lost (Hellertown) Cave, three-fourths mile east of Hellertown, the Tomstown consists mainly of fairly massive dolomitic limestones with only occasional shaly bands. Just east of the cave opening is the poorly exposed layer of sandstone mentioned above.

A short distance south of Leithsville are two Tomstown quarries, in one of which the limestone is unconformably overlain by Triassic red shales and sandstones.

Along the Delaware River road about three and a half miles south of Easton there is an excellent exposure of Tomstown massive dolomite with some interbedded shaly layers. On the top of the hill about two-thirds of a mile to the west similar rock appears. In one place on the farm of the late Prof. Edward Hart there is a small cave.

ALLENTOWN FORMATION

Distribution.—The strata constituting the Allentown formation are represented in Northampton County by a broad band of magnesian limestones that extends from New Jersey west-southwestward to Lehigh County and underlies the major portions of Easton and Bethlehem. Also they form the floor of the larger part of the Saucon Valley and occur in the extreme southeastern corner of the county in the vicinity of Coffeetown and Frya Run. Another small area is located along Catasauqua Creek a short distance north of the town of Catasauqua.

Where the formation crops out along the Lehigh River and smaller streams, fine opportunities are offered for detailed study. It has been quarried in scores of localities and these quarries, now in large part abandoned, are also useful in geologic investigations. Residual soil and glacial deposits conceal the limestones on the uplands.

Lithologic characteristics.—The Allentown formation consists of dense bluish-gray to gray magnesian limestones in beds mainly from six to eighteen inches thick. Some shaly phases contain thinner beds whereas occasional layers are several feet thick. The thicker beds, however, break into thinner laminae on weathering.

One of the most characteristic features of the strata of this formation, and one which is fairly diagnostic, is the alternation of dark and light beds. In an operating quarry these distinctions of color are not readily observable whereas they are prominent in old quarries and in natural outcrops. They are mainly due to different amounts of carbonaceous matter but in part to varying amounts of magnesian carbonate. Those strata with high magnesian content which in fresh fractures may be grayish-blue, assume a lighter color on long exposure to the weathering agents and may even become chalky white and thus present a striking contrast to those beds with less magnesia which undergo less change in color. This criterion of alternating beds of different color for the separation of the Allentown from the Tomstown and Beekmantown unfortunately can not be used everywhere because it is not developed in every exposure. Also, some slight development of this same feature has occasionally been noted in the Tomstown formation.

Shaly bands occur in the Allentown formation but are much less

common and thinner than those of the Tomstown. Bedding plane surfaces with silvery glistening overlapping flakes of sericite mica are noted in many exposures. These bear witness to the original argillaceous content of the strata and the subsequent metamorphic processes that developed the crystalline sericite.

Oolites are conspicuous as distinct layers or lenses and also as isolated grains. On fresh surfaces they are not plainly noticeable but can readily be observed on weathered rock. They vary greatly in size from microscopic grains to spherules resembling buckshot. In places they are white but elsewhere dark, almost black. An unusual variety of oolite occurs in a discontinuous layer in a quarry in the Allentown limestone on the right bank of Monocacy Creek about half a mile north of the Bethlehem-Shoenersville Road. The lower part of each spherule (usually one-half) is dark and the upper part white. This occurrence has been described by E. T. Wherry[82] who explains the phenomena as produced by the removal of most of the calcareous matter from dark impure oolites by solution and the collection of the dark-colored insoluble residue in the lower half of the resulting cavities. Infiltrating waters at a later stage filled the upper half of these openings with crystalline calcite. So far as known the occurrence is unique. Oolites are generally prominently developed in association with heads of *Cryptozoa,* either forming distinct layers or as isolated grains. Besides true oolites, one frequently finds weathered surfaces in which small roughly spherical to angular particles are abundant. Commonly they are darker than the dolomite matrix and smaller than the oolites.

A careful examination of the Allentown limestones will usually reveal some rounded grains of clear quartz. These suggest wind action since they are so much coarser than the particles composing the limestones. During heavy storms occasional grains of beach sand may have been blown from the nearby land. Layers of quartz grains up to six or eight inches in thickness occur in several localities. Almost invariably these sand layers are strongly cross-bedded. On fresh surfaces the rock is gray but becomes brown on weathering, by the oxidation of contained pyrite.

Ripple marks, both large and small, are common in the Allentown limestones with mud (sun) cracks and edgewise conglomerate (intraformational breccia) likewise developed in places. The bedding plane surfaces generally are rough. The described phenomena indicate a shallow-water origin and explain the local variations in the strata even within short distances. As a local example, in the Chapman quarry of the Bethlehem Steel Co. a five-inch bed thinned out to prac-

[82] Wherry, E. T., A Peculiar Oolite from Bethlehem, Pennsylvania: U. S. Nat. Mus. Proc., vol. 49, pp. 153-156, 1915.

tically nothing within thirty feet. Other beds have been noted in which great variations in thickness as well as lithologic characteristics of the beds take place in short distances. Sections of exposures mean little for this reason and exact correlation of strata is impossible except where the exposures are in close proximity. No key bed or horizon marker has been found in the entire formation. Black flint such as occurs in the Tomstown is well developed in certain localities.

Mineralogical composition.—The microscopic examination of the Allentown reveals little other than calcite, dolomite, quartz, sericite and carbonaceous matter with occasional crystals of pyrite. In a microscopic study of the insoluble residues made by B. Frank Buie and described in an unpublished thesis, other minerals were noted. He examined carefully the insoluble residues of eleven specimens of Allentown limestone from the Chapman quarry of the Bethlehem Steel Co. east of Bethlehem. Quartz was almost the only mineral recognized in those grains that failed to pass through a 200-mesh screen, but in the finer material he identified feldspar, zircon, tourmaline, rutile, cyanite, corundum, garnet, topaz, pyrite, galena and possibly fluorite. He regards the pyrite and galena as authigenic and the others as detrital. The following descriptions are quoted from Buie's thesis.

Quartz. Quartz is the predominant species in the residues of all the samples of limestone studied. All the quartz observed was detrital, the grains varying from subangular to sub-rounded forms. The degree of rounding varies with the size of the grains, the larger grains being more rounded and the finer ones more angular. The size of the quartz grains commonly ranges from less than 0.02 mm. to about 0.5 mm. in diameter, though in some samples there is a very minor proportion of grains which are from 1 to 2 mm. in diameter. The grains exhibit a minutely pitted or "frosted" appearance, which is one of their outstanding characteristics when viewed with a microscope. This "frosting" is particularly well developed on the larger grains.

Feldspar. At least two varieties of feldspar are found in these residues, one being microcline and the other a calcic variety of plagioclase. Some of the microcline can be recognized by the characteristic twinning, and the index of refraction and extinction angles are helpful in deciding the variety of plagioclase present, but frequently the grains are decomposed to such an extent that definite determinations cannot be made. Accordingly, it is advisable to use the group term "feldspar" without attempt to differentiate into specific minerals.

Feldspar is the only mineral which has been found in any of the residues in a quantity comparable to that of quartz. A mount made of the light portion of the silt-size of one sample is composed almost entirely of feldspar. In that portion of the residue coarser than 200-mesh, however, quartz is practically the sole constituent, and for the whole residue, the quartz is several times more abundant than all other minerals combined. This particular sample of limestone was from a 3¾-inch bed of dark, very finely crystalline stone, of which the insoluble residue constituted less than one per cent.

Some feldspar was found in the silt grade of all the residues studied. The grains are sub-rounded to sub-angular or irregular in shape. There

are present no crystal outlines or any other features which indicate that this feldspar is authigenic. One grain was observed which is composed of part feldspar and part quartz, the two portions apparently never having been separated. The grains of feldspar are colorless, ranging from almost opaque to transparent, depending upon the degree of decomposition on the surface. They are never so fresh in appearance as is the quartz. Some cleavage lines can be distinguished, though usually these are not very distinct. Some grains that are not too badly altered show a biaxial interference figure with broad, rather indistinct brushes.

Tourmaline. Tourmaline is of common occurrence in all the residues studied. It is found principally in the silt grade, though the residue from one sample contains some grains of -150, +200 mesh size. In an assemblage of minerals, tourmaline can be easily spotted because of its strong absorption parallel to the slow vibration direction.

No authigenic tourmaline is found in these residues, but the detrital grains are of two rather distinct types. A rounded to sub-rounded variety, which is usually yellow to dark brown to nearly black in color, is most common, while there are occasional grains of a variety which is angular to sub-angular in shape and light to dark green in color. Not all of the green tourmaline is highly angular, but some of it has very sharp angles and although the evidence is not conclusive, it is highly suggestive that these more sharply angular grains have had a different history from that of the more rounded ones.

Inclusions are frequently found in the tourmaline grains. These are usually globular or irregular in shape, though one showing crystal terminations—and which appears to be zircon—was noticed.

The optical properties observed are those that are normal for tourmaline.

Zircon. The occurrence of zircon in these residues is similar to that of tourmaline, except that there is a smaller proportion of zircon present.

These grains are usually without color, though some are a very pale yellowish brown and others a pale rose-pink. Color can best be observed with the medium power objective, as there is tendency for all the grains to appear colorless under high power. Both rounded and elongated grains occur. The elongated ones are usually rounded at the ends, and in cases where an angular termination does occur this is probably due to fracturing suffered by the grain subsequent to its having undergone the greater part of its transportation. There are some grains which approach perfection in rounding, being very nearly spherical. No relation between color and degree of rounding is apparent.

Some grains contain small elongated inclusions, of undetermined nature.

The optic properties observed are those that are normal for zircon. The elongated grains are usually elongated parallel to the principal crystallographic axis, and therefore give pseudo-biaxial or "flash" interference figures.

Rutile. Rutile was identified by the rich brown color, parallel extinction, very high refractive index, high birefringence, maximum absorption parallel to long axis, and oblique striations, all of which were evidenced on one prismatic grain which shows only a moderate degree of abrasion. Numerous other grains which are irregular in shape, but which appear to be the same mineral, occur in this and in the silt portions of the other residues. There is a gradation in color from amber to dark brown. The darker grains frequently appear to be opaque, unless the condenser lens is inserted.

Cyanite. Cyanite is of very sparse occurrence in these residues, there being not more than three or four grains in any one mount, and none at all in some. The grains show well-developed cleavage, and only a slight degree of rounding. They are very weakly pleochroic, from colorless to pale bluish-green. The grains are fresh and clear, showing no decomposition. A biaxial interference figure usually can be observed.

Corundum. Corundum is also of very sparse occurrence in the resi-

dues. The grains are angular to sub-angular, with uneven fracture and some re-entrant angles. They are colorless, and exhibit no pleochroism. Some grains were oriented so as to give a good interference figure. The figure is uniaxial negative, though in some grains which do not show complete extinction a slight separation of the arms of the cross upon rotation was observed.

Garnet. In several of the mounts of the silt material there are a few sub-angular grains of a red to reddish-brown isotropic mineral which has high refringence and which is intricately fractured. There is little doubt but that this mineral is garnet, but the statement should be made that it may possibly be red spinel. However, the rarity of this latter mineral as compared to garnet is taken as an additional point in favor of the questionable minerals being garnet.

Topaz. In the mounts of the heavy fractions of the silty portions of two residues several grains of topaz were observed. These grains are sub-angular, colorless and "fresh" without pleochroism, have high index of refraction and low birefringence, and give a biaxial positive interference figure.

Fluorite. Occasional grains of a substance which appears to be fluorite are found in the silt grade. These grains are isotropic, and have a peculiar bluish-gray pearly luster by reflected light. They are sub-angular in shape, and sometimes show cleavage (pair) in two directions.

Although this work has not been advanced far enough to permit definite conclusions being formed, certain inferences as to the kind of rocks from which the detrital grains were derived can be drawn. As a possible source of an assemblage of minerals such as is found in these residues, we have to consider: (1) acid or intermediate igneous rocks, (2) acid or intermediate metamorphic rocks, and (3) pre-existing sediments.

The writer does not believe that any one of these types of rocks alone has been the source of the detrital minerals of the Allentown limestone. The occurrence of well-rounded zircon and fairly well-rounded tourmaline with more angular grains of the same and other minerals, especially tourmaline, topaz, garnet, and corundum, seems best explained on the basis of different source-rocks—that is, by considering the well-rounded grains to have been derived from pre-existing sediments. On the other hand, it would be very unusual, if it is not impossible, for plagioclase feldspar to undergo two cycles of erosion, and accordingly an igneous or igneous-metamorphic rock origin must be supposed for that mineral. And, lastly, the cyanite must have been derived from rocks which had suffered at least local metamorphism.

Hills in his microscopic study[83] of the limestones of the Lehigh Valley describes dolocasts which occur in the Allentown and other limestones of the region.

Dolocasts. Dolocast is a term introduced by McQueen to denote the silicified impressions of dolomite crystals. These impressions show very clearly the rhombohedral outline of the dolomite crystals. They are formed largely of white chert, although some are black to gray, and in some cases they are composed of crystalline quartz. The writer's opinion is that these impressions are probably diagenetic phenomena, and the light-colored chert which forms these impressions took its rise very soon after the deposition of the limestone, and is, for all practical purposes, primary. The dark chert seems to be somewhat later, although no conclusive evidence as to the relative ages of the two kinds of chert has been discovered.

Dolocasts are almost omnipresent in the shaly residues of all these limestones. However, in most cases these dolocasts are very small and can hardly be distinguished under the low power of a binocular microscope. At some horizons large and unmistakable cherty dolocasts appear, which are fairly characteristic of those levels. Unfortunately they are not very persistent, and tend to scatter through a considerable vertical range.

[83] Hills, J. M., Jour. of Sedimentary Petrology, vol. 5, pp. 129-130, 1935.

The results of the microscopic studies of Buie and Hills are sufficiently valuable to justify further investigations of the same character.

Chemical composition.—The calcareous strata of the Allentown formation are almost invariably high in magnesia and are properly classified as dolomites. Perhaps, on an average, the $MgCO_3$ exceeds 35 percent although the range is from 5 to over 43 percent. Very seldom does even a single bed have less than 20 percent $MgCO_3$. The only known occurrence of distinctly low-magnesia limestone in this formation in Northampton County is along the Delaware River road about half a mile below the mouth of the Lehigh River where a lense of pure limestone about eight feet long and up to eight inches thick is interbedded with dolomitic strata. A second lense is somewhat thicker and less pure. It is probable that other similar occurrences may be discovered. This practically complete absence of low magnesia limestone at times is useful in distinguishing the Allentown and the Beekmantown formations as the latter contains much stone low in magnesia.

The distinctions between high- and low-magnesia limestones, which are important in field examinations and find application in the study of the Tomstown, Allentown and Beekmantown formations of Northampton County, have been described by the author in a previous publication.[84]

The low-magnesia limestones are soft and easily broken in comparison with the highly dolomitic ones, so that a geologist can with practice rather closely approximate the magnesian content by the hardness and toughness of the stone when struck with the hammer. The dolomitic stones are also finer grained and more compact than the less magnesian ones of the same region.

High- and low-magnesia limestones can readily be distinguished on weathered surfaces. The high magnesia limestones contain numerous straight cracks running in all directions, along which vein material has commonly been deposited in layers so extremely thin that the freshly broken surface scarcely indicates their existence. On being exposed to the weathering agents these cracks furnish access to dissolving fluids and the weathered surface of the rock looks as though someone had hacked the stone with a steel cutting implement. Where high and low magnesian limestones are interbedded, the contrast on weathered surfaces is striking.

The dolomitic limestones likewise have many more gash veins of quartz and calcite than do the purer limestones. There is also a greater amount of quartz in the vein fillings of the dolomites.

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[84] Miller, B. L., Limestones of Pennsylvania: Pennsylvania Topog. and Geol. Survey Bull. M. 20, p. 11, 1934.

The silica content of the Allentown limestones has been investigated at different times because of their use for fluxing purposes by the operators of blast furnaces in the Lehigh Valley. Some analyses show even less than one percent SiO_2 but rock of this high character is uncommon. In quarries worked for flux some beds contain upwards of 10 percent SiO_2 which, of course, is undesirable. A fair average of utilized stone is probably 3 to 5 percent whereas in other places the average may be considerably higher. There is great variation within many of the large quarries.

Analyses of Allentown limestones are given in the chapter on Economic Geology.

Paleontologic characteristics.—Calcareous algae are abundant in the Allentown formation. They have contributed largely to the formation of certain beds and are found at different horizons. They were noted by Prime[85] in 1878 who described them as follows.

> The limestone sometimes possesses a very peculiar appearance, more closely resembling clam shells planted as closely together as possible with their convex sides uppermost. Although this structure has been carefully examined, no nucleus could be found accounting for such a formation.

They have been described as minor folds of inorganic origin. Emerson[86] described and figured a specimen of *Cryptozoa,* a dolomitic limestone from North Greenland and interpreted it as an inorganic structure. He says:

> The figure shows a curious banded concretionary structure in deeper shades resembling the landscape marble from Cotham, England. It is a distinct schlieren structure in a sedimentary rock, as if a heavier layer had settled upon a lighter, and the latter had at stated points risen up into the former. The lines of flow (are) marked by a delicate banding, and expanded outwardly into a fan structure.

In recent years *Cryptozoa* have been accepted by geologists generally as organic structures. By some they have been regarded as animals, somewhat similar to corals or bryozoa but by most are considered as calcareous algae. Internal structures are not preserved so that their classification has been difficult.

On a bedding plane surface the *Cryptozoa* appear as small lumps from half an inch in diameter and about the same height to heads four feet in diameter and one to four inches in height. Some of the larger forms have a pimply surface of minor structures. In cross section they present a series of thin convex layers of dolomite that may aggregate more than a foot in thickness. In places certain layers weather much whiter than the matrix rock and at a distance a line of these heads appears as a series of folds or loops. The heads in association are generally of about the same size but not always.

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[85] Prime, F., Report DD, Pennsylvania Second Geol. Survey, pp. 14-15, 1878.
[86] Emerson, B. K., American Geologist, vol. 35, p. 98, 1905.

Of the *Cryptozoa* observed in the Allentown dolomitic limestones of the Lehigh Valley there is a great variety. It is probable that a detailed paleobotanic study of these forms will result in the establishment of several different species but up to now no such investigation has been made and they are all classified as *Cryptozoon proliferum*.

In an article by C. L. and M. A. Fenton (bibliography 1937), calcareous algae from the Allentown limestone have been described as *Dolatophycus expansus* from Raubsville and *Anomalophycus compactus* from Portland, Northampton County. These forms have previously been called *Cryptozoa*.

Other species have been named in both New York and Maryland.

Cryptozoa have been used in the Lehigh Valley as criteria for the differentiation of the Allentown from the Tomstown below and the Beekmantown above. Some questionable forms have been observed in the Tomstown, particularly in a quarry on the right bank of the Lehigh River opposite Freemansburg, but in no case have any *Cryptozoa* been positively identified in this formation in this section. Undoubted *Cryptozoa* have been noted in the Martinsburg limestones northeast of Howertown but in rock of entirely different character from that of the Allentown formation.

Animal remains are extremely rare in the Allentown but a few have been found and it is hoped that careful search will result in other discoveries from time to time. A few specimens of the brachiopod *Lingulepis acuminata* have been found in a quarry about one and a half miles southeast of Catasauqua in Lehigh County but only a short distance from the Northampton County line. Weller[87] reports fragments of an Upper Cambrian trilobite, *Solenopleura jerseyensis* associated with an abundance of *Cryptozoa* in the southernmost quarry below Carpentersville, New Jersey, just across the Delaware River from Raubsville, Northampton County.

While B. Frank Buie, Fellow in the Lehigh University Institute of Research, was studying the insoluble residues of some specimens of Allentown limestone from the Chapman quarry of the Bethlehem Steel Co., located on the north side of the Lehigh River between Bethlehem and Freemansburg, during the scholastic year 1931-1932, he discovered some microscopic spherical siliceous forms of apparent organisms. Specimens were submitted to three of the outstanding specialists in the group of the foraminifera, all of whom agreed that the forms were organic but questioned whether they were foraminifera. Buie planned to continue his studies and eventually publish his discovery but his transfer to Harvard University interfered.

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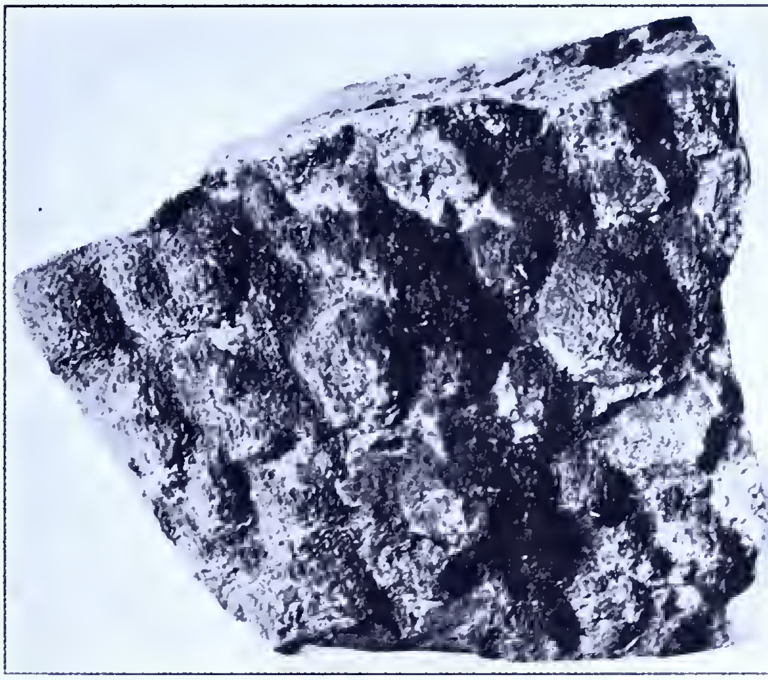
[87] Weller, Stuart, Report on Paleontology: New Jersey Geol. Survey, vol. III, p. 13, 1903.

PLATE 13.

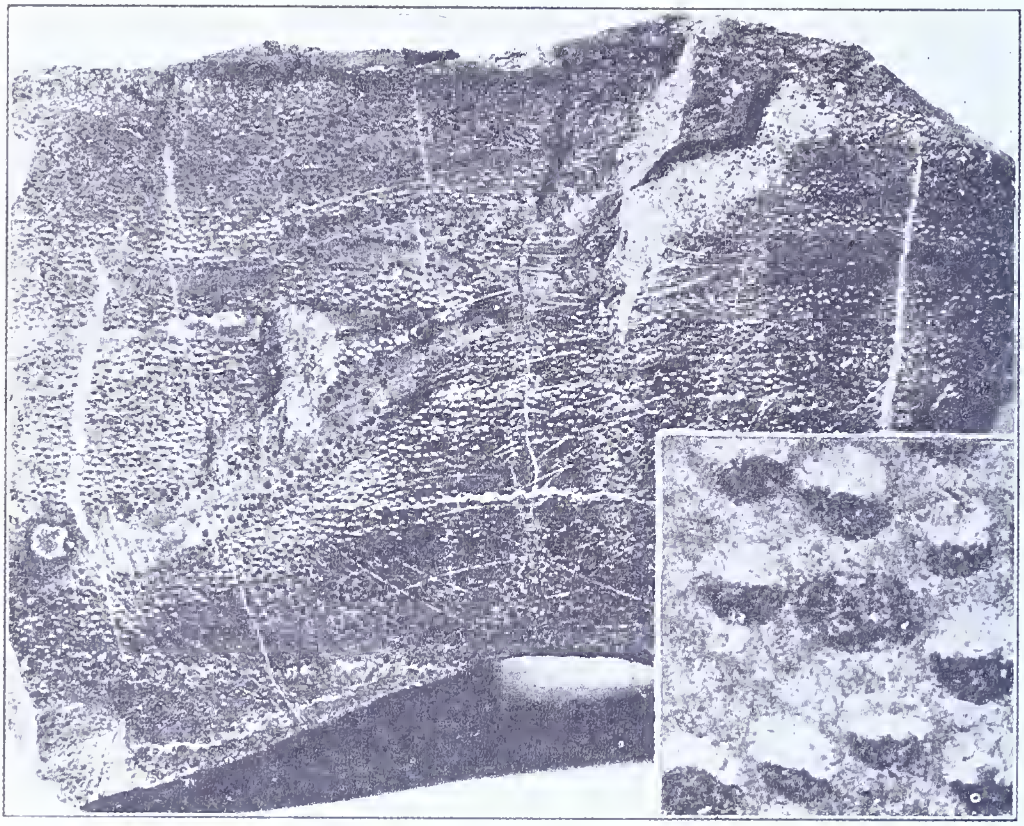


A. Top view.

B. Side view.

C. Side view.

Cryptozoon proliferum, common plant fossil in Allentown limestone.



A. "Half and half" oolite, Allentown limestone, west bank of Monocacy Creek, Bethlehem.

B. Piece of Allentown limestone, showing light and dark strata and a gray band with small Cryptozoon proliferum.

Later J. M. Hills[88] in his more extensive investigations found many specimens of these same organisms in the Allentown limestone, sufficient to determine definitely their zoologic classification. He says:

> These foraminifera are all of arenaceous types and are very simple in form. The majority have ovoid tests with simple apertures. Some, however, have tests which are nearly spherical, and many have necked apertures. A very few have as many as three or four chambers and a complex curved neck. The foraminifera occur most abundantly in the lower division of the Allentown . . . but some are found at lower horizons. These fossils present a most interesting opportunity for further study in the residues, as they are probably the oldest representatives of their order yet found in this country.

Thickness.—As with the other Paleozoic formations of Northampton County, the thickness of the Allentown formation is undetermined. No exposure of the entire thickness is known in the region and the absence of any key bed or any group of beds that can be identified in different exposures, as well as the complicated structures, explain the lack. Thicknesses of 800 to 1,000 feet have been measured in several localities where the entire formation was not exposed. Along a ravine near Hope 1,300 feet of Allentown beds was measured and neither upper nor lower contacts present. The best estimate that can be made at the present time is that the maximum total thickness is 1,500 to 1,600 feet and perhaps a few hundred feet more. As is usual in shallow water deposits the thickness varies greatly in a short distance although concealed faults may be the explanation for these marked changes.

Name and correlation.—The Allentown limestone has been so named because of its extensive and typical development in and about Allentown, Pennsylvania. The name was suggested by Wherry[89] in 1909. It seems to be the equivalent of the Conococheague formation in the Chambersburg[90] region although there are some essential lithologic differences. Although the author has used the name Conococheague in other places, he is now inclined to return to the local name until careful geologic investigations have been made in the intervening area.

E. O. Ulrich regards the Allentown as the base of his Ozarkian period and the Pennsylvania Geological Survey places it at the base of the Canadian period. The U. S. Geological Survey regards it as Upper Cambrian, which meets with the approval of the author.

Stratigraphic relations.—As stated above, the Allentown formation overlies the Tomstown and with apparent conformity, even though formations are missing which appear between these two in the south-

[88] Hills, J. M., Jour. of Sedimentary Petrology, vol. 5, p. 130, 1935.
[89] Wherry, E. T., Science, new series, vol. 30, p. 416, 1909.
[90] Stose, G. W., U. S. Geol. Survey, Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), 1909.

central portion of the State. If there is an appreciable time gap here, it is hoped that evidence of the events of that time will eventually be obtained.

The Allentown strata pass beneath the Beekmantown and again there seems to be perfect conformity. This contact is well shown in the exposed section along the Delaware River road about one and a half miles north of Chestnut Hill. It is difficult to determine the particular place to draw the separation line inasmuch as certain transitional beds might with almost equal reason be included in either formation but within a few feet distinctions are sufficiently great for ready differentiation of the two.

Although in general all the Paleozoic formations of the county appear as outcropping bands in order of decreasing age, there are several places where folds or faults have brought certain formations to the surface in other than the regular arrangement. The general dip of all the strata is to the northwest at varying angles but complex structures have resulted in varying dips and strikes.

Local details.—There are so many and such excellent exposures of Allentown strata along the Lehigh and Delaware rivers, the Monocacy and Bushkill creeks and minor streams that it is hard to select certain ones for special mention. A few examples of sections that show special features are selected.

There is an excellent exposure of Allentown beds in Bethlehem along the Central Railroad of New Jersey from New Street bridge eastward. The alternating dark and light bands are well shown with *Cryptozoa,* mud (sun) cracks, edgewise conglomerate, and ripple marks. Sandy layers are present which in a few places are almost pure quartzitic sandstones. These exhibit excellent cross-bedding on weathered surfaces.

The Chapman quarry of the Bethlehem Steel Co. along the Lehigh Valley Railroad east of Bethlehem shows a variety of strata, thick and thin beds, some shaly, some high in silica, others low, *Cryptozoa,* ripple marks, veins of calcite and quartz, some geodes, folds, faults and abundant joints, varying dips and strikes and deep clay pockets.

A roadside outcrop of Allentown formation half a mile north of Butztown shows a fine example of edgewise conglomerate in which the dolomitic fragments are enclosed in a siliceous sand matrix.

In a quarry on the south side of the Bethlehem-Easton highway about one-quarter mile west of Farmersville, one massive bed of dolomite, about twenty inches thick, is a conglomerate with some fragments as much as six inches long and two inches wide. In places the matrix is a siliceous sand. One interbedded shaly layer shows excel-

lent mud cracks. Torsional joints filled with calcite veins were noted and also minor faults.

The fine exposure along the Central Railroad of New Jersey just east of Nancys Run shows the alternating light and dark bands in the eastern portion. Ripple marks, cross-bedding in the sandy beds, oolites, edgewise conglomerates, and quartz veins are present. There are numerous faults, one of which is of major size and has overturned a great thickness of strata, the overturning best shown by the reversed position of the heads of *Cryptozoa.*

The large Glendon (Sampson) quarry along the Central Railroad of New Jersey in West Easton shows strata of fairly regular character with beds averaging about one and a half feet in thickness. *Cryptozoa,* mud cracks, calcite veins, three small caves, folds, faults, and slumping are all noticeable features.

The fine section along the Delaware River in Easton shows few *Cryptozoa.* They are more common in the north portion of the exposure.

Just south of Raubsville along the Delaware River is the north wall of a long-abandoned quarry that contains some of the finest ripple marks in the region. As they are on the lower side of a slightly overturned bed, they are casts of the original markings. They measure over a foot from crest to crest and extend for more than fifty feet.

Near the foot-bridge across the Lehigh River in South Easton there is a fine exposure of Allentown strata showing a variety of textures and structures. Chert, oolites, stylolites, cross-bedded sandy layers, shaly laminae, *Cryptozoa,* interbedded high and medium magnesian beds, quartz veins, folds, faults and slickenslided surfaces have all been noted.

The Roberts and Walz stone quarries about half a mile south of the mouth of the Lehigh River along the Delaware River Road present excellent exposures of the Allentown strata. In the Walz quarry there are large and small *Cryptozoa.* One head measured three and one-half by four feet across and fourteen inches thick with small knobs over the surface about one inch in diameter and one-third inch high. A layer of sandstone about one inch thick was also observed with some shaly beds, many gash veins of quartz and calcite and a small drag fault. The weathered surface of the dolomite showed the slashed character described on a previous page.

ORDOVICIAN SYSTEM

Beekmantown Formation

Distribution.—The Beekmantown strata constitute the surface indurated rocks in a broad band from one and one-half to four miles

in width extending continuously across Northampton County between the Lehigh and Delaware rivers. Surficial soils and glacial deposits conceal them generally over the uplands but there are abundant outcrops along the stream valleys. In scores of places the limestones, of which the formation is almost exclusively composed, have been quarried for road metal, for flux and for the manufacture of lime, and these quarries also furnish opportunities for study. With the exception of a small area in the southwest portion of Easton, the Beekmantown has not been recognized south of Camels Hump and Chestnut Hill within the county. It occurs in the Lehigh County portion of Saucon Valley but does not seem to be present in this valley in Northampton County.

An isolated fault block area of the Allentown, Beekmantown and Jacksonburg in the vicinity of Portland extends from the Delaware River in a gradually narrowing band to Johnsonville. It has been quarried and burned for lime in several places along Jacoby Creek and its tributaries.

The band of Beekmantown limestones is bounded on the south by the older and underlying Allentown strata and on the north by the younger and overlying Jacksonburg cement limestones.

Lithologic characteristics.—The Beekmantown formation in Northampton County consists almost entirely of alternating calcareous strata of varying composition and physical properties. High magnesian limestones (dolomites) are predominant, especially in the lower part, but there are many interbedded strata containing a medium to low percentage of $MgCO_3$. The dolomitic beds are generally more massive, considerably harder and tougher and can be readily differentiated by the driller and by the quarrymen. For some years the Lawrence Portland Cement Co. operated a quarry along the Lehigh River north of Catasauqua where the low magnesian stone used in cement manufacture was picked by hand by the workers from the high magnesian stone that was crushed for flux, ballast and concrete. Both kinds of rock were shot down together from the quarry face.

The dolomitic beds range in thickness up to eight to ten feet and scarcely show lamination or bedding planes except on weathered surfaces whereas those layers containing a moderate or small amount of $MgCO_3$ are mainly less than one foot thick and in places so thinly laminated as to suggest shale. Thin beds or lenses of true shale occur although much less common than in the Allentown and Tomstown formations.

In many exposures the more highly magnesian beds are marked by numerous gash veins of quartz and calcite. Such veins are rare in the

adjoining strata with low magnesia content. During folding the more massive, brittle and stronger dolomitic limestones were broken and jointed while the thinner bedded low-magnesian strata developed flowage, and fewer open joints persisted. There are abundant illustrations of the slippage of one bed on another in these purer limestones.

The joints in the dolomitic layers have been filled with quartz, dolomite and calcite. Many weathered blocks of dolomite have a maze of intersecting quartz veins projecting prominently above the surface.

Another prominent feature of the Beekmantown dolomitic limestones of the region, by which they can be distinguished from the underlying strata of the Allentown and Tomstown, is a conglomerate structure shown on weathered surfaces but scarcely apparent in the freshly broken rock, which is dark steel blue and appears fairly homogeneous. Irregular brownish-gray sandy patches project above a surface of bluish-gray matrix, and suggest organisms of the general character of *Bryozoa,* although no evidence of their organic nature has been obtained. The portions of each type are about equal in amount and there is no parallelism of arrangement. The origin of this type of rock is not known. The irregular shape of the patches does not seem to be what one would expect if waves had broken up earlier thin-layered deposits and transported the fragments to a place where a different type of deposit was forming. If they are of organic origin one may assign them to the plant kingdom and interpret them as sea weeds *(Fucoids?)* or perhaps to the animal kingdom as *Bryozoa* or allied forms.

Elsewhere in the State the Beekmantown formation contains in many places a banded variety of dolomitic limestone made of parallel dark and light layers or lenses, generally about one-fourth to one-half inch in width. This type has been observed in Northampton County in only a few places, the best example being in an abandoned quarry about three-fourths mile southwest of Portland.

Coarse dolomitic conglomerates occur in several places and also greatly brecciated layers, some of which are original structures and others secondary. The individual fragments range in size up to eight or ten inches. Thin bands of edgewise conglomerates and oolites are occasionally seen.

True shales, without calcareous matter, are uncommon in the Beekmantown and where present are thin and thus furnish another criterion for distinguishing this formation from the underlying rocks. Thin layers of argillaceous material, now altered to sericite mica, occur on many bedding plane surfaces.

Siliceous beds in which there is a large percentage of quartz grains are rare. Secondary black flint lenses and irregular masses of large and small dimensions, formed by the replacement of limestones and dolomites, are prominent in regions that have undergone considerable disturbance by close folding and faulting but elsewhere are seldom noted. As the limestones are removed by solution these remaining flint masses accumulate in the residual soils and may be abundant.

Lithologically it is generally possible to separate the Beekmantown from the Allentown and the Tomstown strata by the characteristics described. However, some of these features are not confined to the Beekmantown and again, no one of them may be exhibited in local restricted exposures; also the low-magnesian limestones of the upper Beekmantown may be confused with the basal limestones of the Jacksonburg. Therefore, there is room for difference of opinion in certain localities and it is to be expected that other maps will be prepared from time to time in which the stratigraphic lines will not agree exactly with those shown on the accompanying maps.

Chemical composition.—The strata of the Beekmantown formation show wide variation in chemical composition, particularly with reference to the $MgCO_3$ content. To the writer's knowledge, cement companies looking for accessible high-grade stone to ''sweeten'' the low-lime cement rock have discovered numerous outcropping beds of Beekmantown limestones containing from 90 to 95 percent $CaCO_3$ and only 1 to 3 percent $MgCO_3$. In several cases they have incurred considerable expense in drilling certain properties, only to find that this type of stone was interbedded with dolomitic limestones containing over 40 percent $MgCO_3$ and that it would not be possible to operate a quarry by steam-shovel for material usable in the manufacture of portland cement. It was feasible for cement companies to operate such quarries only during the days when hand-loading prevailed and the low-magnesian stone could be shipped to cement plants and the high-magnesia could be sold to iron furnaces for flux or used for ballast or concrete.

No locality in Northampton County has been investigated where, under present economic conditions, a large amount of low-magnesian stone of this formation might be quarried without being mixed with an excessive amount of dolomitic stone. In Berks County, the writer found a quarryable thickness of high-grade limestone within the Beekmantown, and it is not improbable that this county may locally contain similar material.

Over thirty years ago a property northeast of Hanoverville was selected as the site of a cement plant (Lily White Cement Co.), the

stone to be taken from a nearby quarry in the Beekmantown. After the foundations of some buildings had been constructed it was discovered that the admixture by interbedding of the low- and high-magnesian stone made the project commercially impossible. If the strata had been horizontal, there might have been more chance of success but unfortunately the beds at that locality are intricately folded. For some years the Industrial Limestone Co. separated the low-magnesian limestone and shipped it to a local cement company, crushed some of the gnarly, highly siliceous stone for road metal and concrete, and burned the purer dolomitic layers for lime.

Prof. D. S. Chamberlain, Lehigh University, made a detailed study of some of the layers exposed in the quarry face a few years ago, particularly with reference to a prominent dolomitic bed. A photograph of the quarry and a table of analyses are abstracted from his report.

Analysis of limestone from Industrial Limestone Co. quarry, Hanoverville

[D. S. Chamberlain, analyst]

No.	SiO_2	$Fe_2O_3+Al_2O_3$	$CaCO_3$	$MgCO_3$
1	5.74	3.72	86.75	2.81
2	4.30	1.48	61.80	32.50
3	6.28	10.82	41.06	40.90
4	3.68	1.84	64.80	30.03
5	2.42	12.46	85.50	1.25
6	5.18	17.78	38.10	38.05
7	6.30	1.14	89.25	2.34
8	5.40	1.12	55.60	38.60
9	3.82	17.54	57.65	21.02
10	7.46	0.50	88.94	2.85
11	5.64	1.18	78.00	15.80
12	4.20	0.46	89.85	6.44
13	4.06	9.14	79.55	6.33
14	5.80	5.58	54.53	34.05
15	4.34	10.50	80.00	4.89
16	6.56	0.82	56.85	36.65
17	5.70	0.24	92.45	2.02
18	6.48	4.04	88.45	2.77
19	4.88	0.82	55.44	38.94
21	6.52	0.88	55.15	38.21
22	5.54	5.08	84.97	3.73

The stone shipped from this quarry to one of the cement plants is shown in the following analyses:

Analyses of limestone from quarry of The Industrial Limestone Co.

	A	B	C
$CaCO_3$	94.37	92.70	96.50
$MgCO_3$	2.24	4.15	1.76
$Al_2O_3+Fe_2O_3$	0.74	0.34	0.28
SiO_2	2.26	1.5	0.54

The Lawrence Portland Cement Co. furnishes the following set of analyses of the limestone obtained from the North Catasauqua Beekmantown quarry that was used for cement manufacture.

Analyses of limestones in quarry ¼ mile north of Catasauqua

	1	2	3	4	5	6	7	8	9	10	11
$CaCO_3$	82.12	85.50	79.65	79.03	75.50	85.32	76.94	87.23	92.57	88.30	85.63
$MgCO_3$	4.31	3.44	2.98	3.35	6.07	4.07	4.73	4.53	5.10	3.13	6.04
$Al_2O_3+Fe_2O_3$.	3.55	2.14	4.55	5.69	5.41	2.63	4.76	1.87	1.22	3.05	2.85
SiO_2	9.02	7.82	12.91	12.38	12.81	7.43	13.90	5.56	1.94	5.18	5.70

Paleontologic characteristics.—Fossils have been found at several localities in the Beekmantown strata of Northampton County but everywhere so poorly preserved as to make their exact determination almost impossible. The weathered surfaces of many outcrops, especially of those beds low in magnesia, reveal shell fragments and crinoid stems. In general most of the specimens thus far observed are coiled gastropods and cephalopods.

In the old quarry of the Lawrence Portland Cement Co. in North Catasauqua some well-defined coils of a large gastropod can be seen in a very massive dolomitic limestone. Some specimens are as much as five inches in diameter. They are probably a species of *Liospira.* Similar forms and some specimens of *Orthoceras* have been noted in the old quarry of the Parryville Iron Co. just south of Northampton. Some poorly preserved fossils have been observed in the railroad cuts east of Weaversville and in some quarries southwest of Bath.

Fossils have been found in some exposed beds along the highway three-fourths mile north of Steuben Station and in the quarries southeast of Steuben. At the former locality numerous specimens of a small species of *Orospira* occur in slabs of shaly limestone in the fields, and in the quarries some fairly good specimens of *Lophospira gregaria* (Billings) are associated with fragments of undeterminable forms. All of these appear only on the weathered surfaces of the rock.

In some small quarries on the south side of Schoeneck Creek east of Nazareth a few gastropods have been found. A quarry about one mile northwest of Walters contains some limestones with fairly abundant small gastropods. Another fossil locality is an abandoned quarry just south of the large quarry of the Hercules Cement Co. Wherry provisionally identified the following forms from this place: a small species of *Liospira, Orospira* cf *bigranosa* Ulrich, *Hormotoma* cf *H. artemisia* (Billings) and a new (?) species of *Leiostegium.* Other unidentifiable forms are present.

Thickness.—As in the case of the other Paleozoic formations of the region, there is no known place in the county where reliable measure-

ments can be made. Continuous exposures across the entire formation are lacking; minor and major folds and faults are present and dips change so rapidly that one is not justified in assuming the continuance of any dip beneath concealed areas. Attempts to determine the thickness at several points, all of which necessitate several unproved assumptions, have given figures from 700 to 2,000 feet. It is probable that the thickness is approximately 1,000 to 1,200 feet, perhaps less in the vicinity of the Delaware River.

Name and correlation.—In the publication of the First Geological Survey of Pennsylvania, these limestones formed a part of the II Auroral Limestone. They constitute a part of the II Calciferous Limestone of the Second Geological Survey, a part of the Shenandoah Limestone of the U. S. Geological Survey from 1892 to 1908. This series was designated the Kittatinny by the New Jersey Geological Survey. Wherry and Miller in publications beginning in 1909 adopted the local name of Coplay from the town of Coplay, Lehigh County. Later, however, the local name was dropped as the fossils indicate proper correlation with the Beekmantown formation of the Mercersburg-Chambersburg area. This conclusion has been confirmed by E. O. Ulrich.

If and when further paleontologic studies are made of the fauna of the formation, it will be possible to discuss more exact correlations.

Stratigraphic relations.—In the region there are few exposures of contacts of formations. Close association of the Beekmantown and the underlying Allentown seems to indicate conformable strata. There may be a hiatus between the two formations since the New York section contains beds apparently not represented in this region.

The upper surface of the Beekmantown is definitely unconformable with the overlying Jacksonburg in New Jersey as described by R. L. Miller[91]. He also presents evidence to support belief in a probable unconformability in Northampton County but with less positive information.

Local details.—A few localities where certain characteristics of the Beekmantown are particularly well shown are briefly described.

In the east part of Northampton Borough, very close to the contact of the Jacksonburg cement limestone, the interbedding of dense, hard, blue, massive dolomite with shaly, soft high-calcium limestone is shown perhaps as well as in any other place in the county. The limestone beds are prominently pitted on the weathered surface.

[91] Miller, R. L., Stratigraphy of the Jacksonburg Limestone: Geol. Soc. America Bull., vol. 48, pp. 1687-1718, 1937.

The finest example of complicated folding of the entire region is in an abandoned quarry in close proximity to the southeast line of Northampton. The axes of the folds are not regular, some are almost east-west and others nearly north-south. The folding is close; some folds are recumbent. Faults and veins are rare, the strata yielding by bedding plane slippage or flowage instead of breaking. Most of the stone is only moderately high in $MgCO_3$. Flint nodules and weathered, pitted surfaces can be seen. Here is where some massive beds show fragments of *Orthoceras*.

The Reyer quarry, located about half a mile east of the south part of Northampton, shows two phases of the Beekmantown. The north part of the quarry contains two kinds of dolomite, one blue and fine-grained, the other granular and bluish-gray. One bed of intraformational conglomerate contains angular blocks up to eight inches in diameter. An analysis of the dolomite from this portion of the quarry by the Lawrence Portland Cement Co. is as follows:

SiO_2 5.2, $Al_2O_3 + Fe_2O_3$ 4.1, $CaCO_3$ 57.38, $MgCO_3$ 32.83

The south part of the quarry contains some much folded low magnesian limestones, some of which show 92 to 95 percent $CaCO_3$. The dolomite is crushed for concrete and ballast, and some of the pure limestone has been sold to a cement company.

The abandoned quarry of the Lawrence Portland Cement Co. in North Catasauqua, previously mentioned, contains one white dolomitic bed that is beautifully folded. The folding is not apparent in the darker strata above and below.

A large quarry on the south side of the Northampton & Bath R. R. one-third mile southwest of Lerchs Station contains rock varying from almost pure limestone to dolomite. There are overturned folds and gentle anticlines. The dolomitic beds were shattered in the folding and the fractures later filled by quartz and calcite. On weathered surfaces the quartz veins project prominently. The purer limestones yielded by flowage. Pitted weathered surfaces characteristic of the Beekmantown are noticeable.

Three-fourths mile north of Shoenersville along the L. & N. E. R. R., stone varying from medium to high magnesian composition has been quarried. Here the surface of one layer shows numerous nodular concretions (?) the size of a large marble.

A large quarry about half a mile north of Hanoverville exhibits a very complicated joint system in the folded massive dolomites, with numerous veins of quartz and calcite. Low magnesian interbedded limestones yielded by flowage and have few veins, although a few large masses of calcite crystals were noted.

In the main part of the large hillside quarry just north of Brodhead along the Nazareth Highway the Beekmantown dolomite is unusually massive and resembles the Tomstown. Along the road some lower strata are less high in their magnesian content and show the typical mottled and pitted weathered surfaces.

On a prominent hill east of the Nazareth Highway somewhat less than half a mile south of Newburg there are some outcropping beds of high-calcium limestone suitable for portland cement manufacture. This property was drilled to see whether there was a sufficient thickness of low magnesian stone for opening a quarry but interbedded dolomites were encountered. Some of the better stone is conglomeratic and shows mottled and pitted weathered surfaces.

A small quarry and roadside exposures in the northwest corner of Palmer Township show some low magnesian coarsely crystalline gray limestones containing fragments of trilobite cephalons. The Hercules Cement Co. drilled the property but discovered that the high-calcium stone was thin and underlain by dolomite.

The small area of Beekmantown in the southwest part of Easton contains both high and low magnesian stone. Some weathered layers exhibit the typical Beekmantown characteristics of mottled and pitted surfaces.

The exposure of the Allentown-Beekmantown contact along the Delaware River road is excellent. Some of the lowest beds show the characteristic Beekmantown weathering.

Jacksonburg Formation

By Ralph L. Miller

Distribution.—Overlying the Beekmantown limestone in Northampton County is a series of dark-colored middle-Ordovician limestones and argillaceous limestones, which have been extensively employed for the manufacture of portland cement. Various names have been used to designate this series in the past, but in recent years it has become customary to refer to it as the Jacksonburg formation, and to recognize and map two facies divisions. The Jacksonburg has variable characters and thickness in different parts of the county, but is everywhere distinguishable from the underlying dolomitic limestones of the Beekmantown formation and the overlying non-calcareous shales of the Martinsburg formation.

The main belt of outcrop of the Jacksonburg crosses the Delaware into Pennsylvania near Belvidere and enters Northampton County on its east central side. It extends southwestward from here in a con-

tinuous belt 24 miles in length. The belt gradually increases in width from one-tenth mile near the New Jersey border to nearly two miles in the western part of the county along the Lehigh River. Along this belt lie the boroughs of Martins Creek, Stockertown, Nazareth, Bath and Northampton. The Jacksonburg belt of outcrop lies on the northwest side of the larger limestone lowland. The area that it underlies tends to stand at a slightly higher elevation than the main section of the lowland eroded on the Cambrian and Beekmantown dolomitic limestones. However, the topographic break is very indistinct in most places, and over considerable areas no difference of elevation is observable. In the vicinity of Nazareth, on the other hand, the Jacksonburg forms a local level 100 feet above the Beekmantown limestone to the south.

On the northwest side, the Jacksonburg belt is limited by the dissected escarpment formed by the Martinsburg shales. Along the contact between these two formations the topographic break is sharp, the shale hills rising steeply to elevations as much as 300 feet above the limestone level. Throughout the eastern and central parts of the county this escarpment is clearly defined, and the geologic contact can be drawn with considerable accuracy on the basis of topography alone. On the western side of the county the escarpment is more dissected, and the differential levels of the two formations less apparent.

Three restricted areas of Jacksonburg are present in the county beyond the confines of the main belt. On the southeast side of the Jacoby Creek limestone lowland, near Portland, it is locally present in a narrow belt in its normal position between the Beekmantown and the Martinsburg. Only one good exposure of the formation is available, as most of this region is heavily mantled by morainal drift of the Wisconsin ice sheet. A second area of Jacksonburg is downfolded in the central part of the limestone lowland four miles north of Bethlehem and one mile west of Brodhead. This irregular-shaped area, approximately one mile in diameter, furnishes the rock for the National Cement Co., the most recent plant to be erected in the county. A third local area, lenticular in shape and half a mile in longest dimension, is in West Easton near the Lehigh River. A roadside exposure of shale, which is presumably downfaulted Martinsburg shale, lies one and one-half miles southeast of Brodhead. Jacksonburg may possibly be present around the margins of this small shale area, but no exposures of it are known.

The areal outcrop of the Jacksonburg is not extensive. It seems, however, to have formed a continuous deposit of variable thickness over the whole county. Wherever the succession of beds is undis-

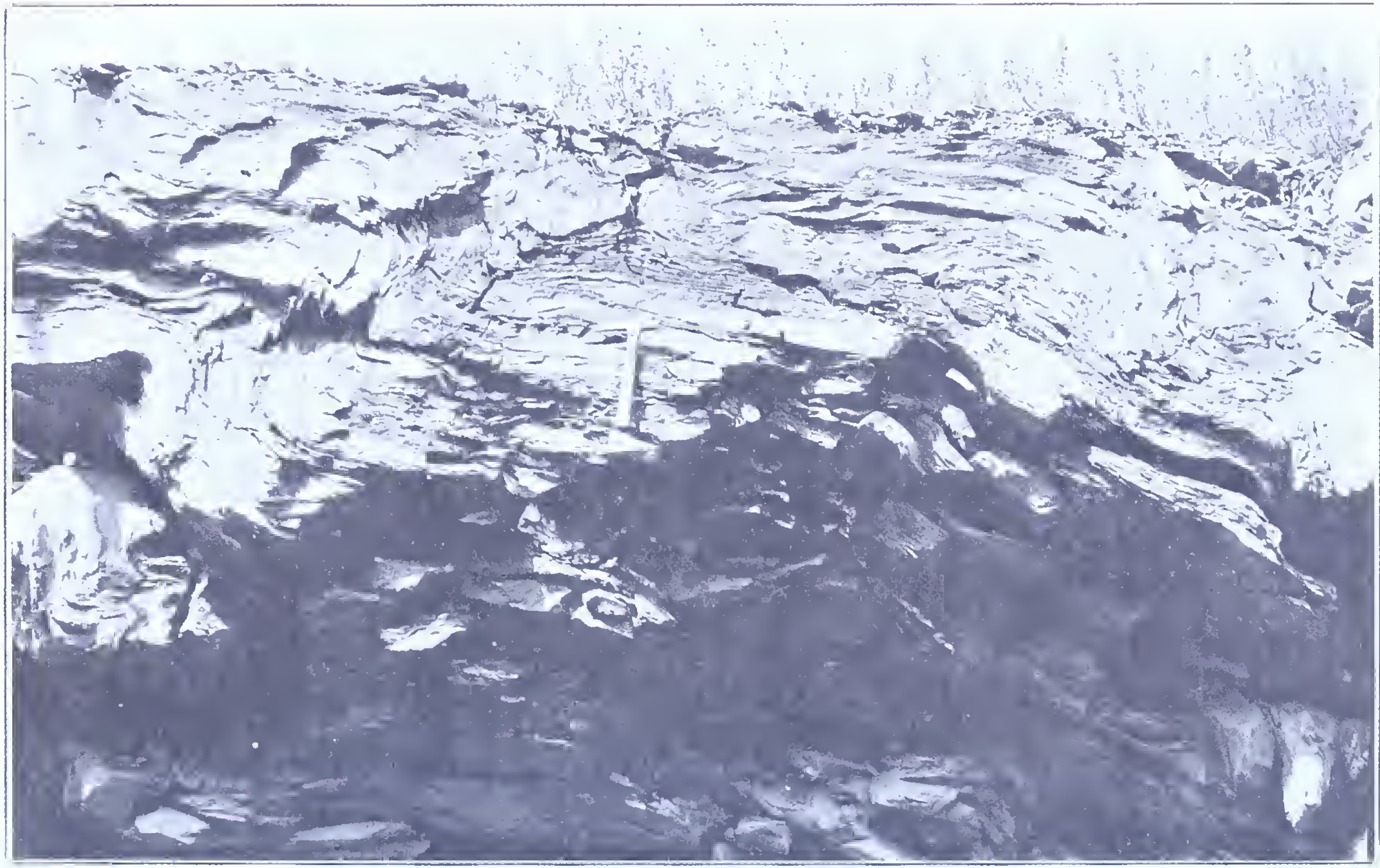
turbed by faulting, the Jacksonburg now appears at the surface between the Beekmantown dolomitic limestones and the Martinsburg shales. A few miles beyond the county borders to the west and to the south, the Jacksonburg is missing at places where its presence is expectable, and nowhere else does it attain the thickness or continuity developed in Northampton County.

Lithologic characteristics.—The Jacksonburg is lithologically distinctive, and is usually easily recognizable in the field. Two facies of the Jacksonburg are developed and are mapped separately over most of the county. The lower part of the formation, the cement limestone facies, is a fossiliferous high-grade, non-dolomitic limestone which varies in color from dark gray to black. It is normally crystalline, the crystals ranging in size up to about three millimeters. In places, however, the texture is so fine that the individual crystals cannot be distinguished with the unaided eye. The bedding of the cement limestone in unweathered exposures is massive, visible bedding planes being spaced from one foot to as much as fifteen feet apart. In weathered exposures, however, solution has emphasized the presence of minor or incipient bedding planes, so that the beds may be as thin as an inch. The cement limestone is relatively competent as contrasted with the overlying cement rock. Mountain-building stresses, to which the region has been subjected, have produced complex folds but unaccompanied by much flowage, shearing, or intricate, small scale distortion. The fossils in the cement limestone are normally visible only on weathered surfaces, but they are not distorted beyond recognition as they commonly are in the cement rock.

The cement limestone is readily dissolved by meteoric waters, so that very few cobbles or fragments of it are to be found in the surface soils. Clay pockets are visible in some of the quarries. The upper rock surface is an irregular solution surface, but solution and weathering do not progress to depths exceeding a few feet, except along major joint and bedding planes.

Overlying the cement limestone facies in all except the northeastern localities, is a more argillaceous facies of the Jacksonburg, to which the name cement rock facies has been applied. The gradation from the cement limestone to the cement rock is by means of intercalation. Argillaceous limestone beds become more abundant in the upper part of the crystalline cement limestone until they exceed the crystalline beds in quantity and thickness. In some of the cement quarries, the transition is quite abrupt so that it is possible to select by eye an exact horizon below which the cement limestone facies is clearly dominant and above which the cement rock facies prevails. This situation exists

PLATE 15.



Crumpled Jacksonburg cement rock containing veins of calcite and quartz. Quarry of Lehigh Portland Cement Co., Bath.

in the quarry of the Lone Star Cement Co. near Nazareth where the lithologic division is clear enough to be apparent in a photograph. Commonly the transition zone may extend for more than fifty feet. Occasional crystalline high-lime beds are present even higher and argillaceous beds even lower. Where exposures are not continuous, this introduces a considerable source of error in the separation of the two facies on geologic maps. It is quite certain that the mapping of this boundary will be subject to some rectification as new exposures become available in areas where outcrop evidence is now scanty.

The cement rock is a black, fine-textured, argillaceous limestone, superficially bearing a closer resemblance to slate than to limestone. Slaty cleavage is irregularly developed, commonly obscuring or entirely obliterating the traces of the original beds. Despite its approximation to the physical characters of slate, the cement rock is distinguishable from the Martinsburg slates by its deep, velvety-black luster and by the absence of color bands. A test with dilute acid will also invariably distinguish the two, as the Martinsburg slates are non-calcareous, and the cement rock seldom carries less than fifty per cent $CaCO_3$. In many quarry faces, veins of calcite and of quartz are present, usually paralleling the bedding in the lower cement limestone facies and the slaty cleavage in the upper cement rock facies. They are much more numerous in the cement rock facies, locally being so abundant and so closely spaced as to give the rock the appearance of layer cake.

In a few quarries, beds of altered volcanic ash (bentonite) are intercalated in the Jacksonburg formation. These beds are usually only a few inches thick, but one in the Nazareth Cement Company quarry is thirteen inches thick. The source of the volcanic ash is not known, but it is presumed to have come from the southeast as volcanic ash beds have not been noted in the Jacksonburg in its northernmost exposures, and they are thinner and seem to be less abundant in rocks of similar age in Lehigh and Berks counties. A list of the exposures of volcanic ash beds noted by the writer is given below. The tabulation should not be considered complete, however, as minute examination of quarry faces frequently reveals altered volcanic ash beds previously unrecorded. Attempts to correlate by use of the ash beds have been unsuccessful, because of the variations in thickness and spacing of the beds over short distances, and because guide fossils by which tentative correlations can be checked, are rare. Several probable correlations are suggested in the table, however.

Bentonite localities in Northampton County

	Thickness in inches	Probable age of enclosing rocks
1. Lehigh Cement Co. quarry, Sandts Eddy. Bed in north end of quarry	.25	Sherman Fall
2. Hercules Cement Co. quarry, Stockertown. West face	.25	Sherman Fall
3. Nazareth Cement Co. quarry, Nazareth:		
Bed 1—155 feet below top of cement limestone facies	1.5	Hull
Bed 2—105 feet below top of cement limestone facies	13.	Hull
Bed 3—north face of quarry in cement rock facies. Separated from Beds 1 and 2 by a fault	5.	Sherman Fall
Bed 4—9 feet above Bed 3	2.	Sherman Fall
4. Lone Star Cement Co. quarry, Nazareth. East face. 110 feet below top of cement limestone facies. Same as Bed 2 of Nazareth quarry	1.5	Hull
5. Keystone Cement Co. quarry, Bath. Southwest corner. 25 feet below top of cement limestone facies	1.5	Hull?
6. Lehigh Cement Co. quarry, Bath:		
Bed 1—south face of south quarry in cement limestone facies. Same as Bed 2 in Nazareth Co. quarry?	13.	Hull
Bed 2—30 feet above Bed 1	1.	Hull
7. Universal-Atlas Cement Co., Northampton. Southeast corner of quarry north of highway. Questionable ash bed	1.	Sherman Fall

Analyses of two specimens of bentonite, Nazareth Cement Co.'s quarry

E. C. Morgan, Nazareth Cement Company, Analyst

	1	2
SiO_2	50.04	63.58
Fe_2O_3	1.80	2.12
Al_2O_3	25.51	18.78
P_2O_5	.21	.18
CaO	.53	.48
MgO	6.88	3.88
SO_3	1.08	1.44
Na_2O	.31	.18
K_2O	5.88	4.65
Ig Loss	7.07	5.35
	99.31	100.64

Paleontologic characteristics.—The Jacksonburg is abundantly fossiliferous at a few localities in Northampton County. Fossils are not well preserved in the formation, however, and normally they can be recognized only on weathered surfaces. In general, the best collecting localities are on the eastern side of the county and the formation becomes less fossiliferous and the fossils increasingly more distorted westward. Along the western side of the county few identifiable forms have been found.

The fauna of the Jacksonburg is composed dominantly of brachiopods and bryozoa, with trilobites, pelecypods, sponges and conularids sparingly represented. The bryozoan *Prasopora orientalis* Ulrich is common throughout the county in the cement rock facies of the Jacksonburg. Because of its massive, compact nature, *Prasopora* is recognizable in rocks where all other forms have been obliterated by deformation. It ranges through the upper three hundred feet of the formation, but has not been found in the lower cement limestone facies or in the overlying Martinsburg shales.

Of the brachiopods, *Dalmanella rogata* (Sardeson) and *Sowerbyella* sp. are most common, especially in the cement limestone facies, but they have been found also in the cement rock beds. The sponge *Receptaculites occidentalis* Salter occurs in the lowest beds at several localities, followed by *Parastrophina hemiplicata* (Hall) which has a considerable range but seems to be confined to the cement limestone facies. Local beds contain abundant bryoza of the genera *Pachydictya, Rhinidictya* and *Monotrypa* but these forms do not seem to be restricted to any particular horizon.

One of the most fossiliferous exposures of the Jacksonburg in the county is eight-tenths mile south-southeast of Portland. Of two quarries here, the southern one just at the base of the Martinsburg shale hills exposes fifty feet of Jacksonburg. The section measured here, with the fossils collected, is as follows:

Section of Jacksonburg formation near Portland

	Feet	Inches	To base of formation Feet
14. Martinsburg.			
13. Covered	38	..	108
12. Gray limestone with abundant *Pachydictya* sp. cf. *P. acuta* Hall, *Rhinidictya* sp., *Strophomena* sp., and *Dalmanella rogata* (Sardeson)	13	1	70
11. Crystalline, massive-bedded, dark-gray limestone	5	10	57
10. Dense, fine-grained limestone	1	10	51
9. Knobbly, thin-bedded limestone containing *Isotelus gigas* deKay, *Sowerbyella* sp., *Rhynchotrema* sp., *Strophomena* sp., *Proetus* sp.; scattered conglomeratic pebbles of underlying limestone in basal bed.	3	10	49
8. Massive bed of fine-grained gray conchoidally fracturing limestone	2	3	45
7. Knobbly beds of crystalline gray limestone containing fragmentary fossils.	8	11	43
6. Dark-gray crystalline limestone with fragmentary fossils; *Dolcroides* sp., ..	5	10	36
5. Knobbly, gray limestone containing *Pachydictya* sp., and crinoidals.	4	..	30

	Feet	Inches	To base of formation Feet
4. Fine-grained gray limestone containing *Streptelasma* sp., *Doleroides* sp., gastropod indet.	5	..	26
3. Crystalline gray limestone in knobbly beds 2 to 6 inches thick, containing abundant crinoid stems of all sizes, *Doleroides* sp., *Leperditia fabulites* Conrad, *Scenidium anthonensis* Sardeson, and *Monotrypa* sp.	1	6	21
2. Covered	42	..	20±
1. Beekmantown.			

Fossiliferous near-basal cement limestone beds are exposed two miles east of Martins Creek. Where the Belvidere highway turns from west to northwest, an abandoned lane continues westward past a large barn at the corner and down a steep hill. A few ledges of crystalline Jacksonburg crop out in the lane on this hill slope in which the following forms were present:

Pachydictya acuta Hall	a	*Rafinesquina alternata* (Conrad)	f
Rhinidictya sp. cf. R. *mutabilis* Ulrich	a	*Strophomena* sp.	r
Lingula elongata Hall	r	*Dalmanella rogata* (Sardeson)	c
Lingula sp.	f	Pelecypod indet.	r
Sowerbyella sp.	c	*Isotelus* fragment	r
Parastrophina hemiplicata (Hall)	c		

Two cement quarries have furnished fair collections of fossils.

In the Sandts Eddy quarry of the Lehigh Cement Company the Beekmantown limestone is in fault contact with the argillaceous beds of the upper part of the Jacksonburg. From different parts of this quarry, the beds of which were not correlated due to folding and faulting, the following were collected:

Prasopora orientalis Ulrich	f	*Brachiopod* indet.	
Sowerbyella sp.	f	*Conularia* sp.	r
Dalmanella rogata (Sardeson)	a	*Calymene* sp.	r
Dinorthis pectinella (Emmons)	r	*Calliops* sp. cf. *C. callicephalus* (Hall)	r
Zygospira sp.	c	Trilobite indet.	

In the Nazareth Cement Co. quarry east of Nazareth, fossils are frequent at several horizons. A continuous section is exposed through 610 feet of the formation. At this point a fault is encountered and beds exposed in the north face of the quarry above the fault are believed to be higher. The sections as measured here with the fossils collected are given below:

Section of Jacksonburg formation at Nazareth

		Feet	Inches	Top of bed to base of section Feet
B5.	Black, argillaceous limestone with slaty cleavage	20	..	54
B4.	Altered volcanic ash bed	..	2	34
B3.	Black argillaceous limestone with slaty cleavage	9	..	34
B2.	Altered volcanic ash bed	..	5	25
B1.	Black argillaceous limestone with slaty cleavage, probably higher than Bed A7	25	..	25
	Fault			
A7.	Black argillaceous limestone in massive beds with slaty cleavage; contains *Prasopora orientalis* Ulrich	150	..	610
A6.	Black argillaceous limestone with slaty cleavage. Top layers contain *Prasopora* ? sp., *Dalmanella rogata* (Sardeson), *Dinorthis pectinella* (Emmons), *Parastrophina hemiplicata* (Hall), *Calliops callicephalus* (Hall), and *Rafinesquina* sp.	100	..	460
A5.	Gray fine-grained, even-bedded limestone. Top layer contains *Mesotrypa* sp., *Dinorthis pectinella* (Emmons), *Parastrophina* sp., *Dalmanella rogata* (Sardeson), *Sowerbyella* sp., and *Rafinesquina* sp.	105	..	360
A4.	Altered volcanic ash bed	...	13	255
A3.	Gray fine-grained, even-bedded limestone	50	..	254
A2.	Altered volcanic ash bed	...	1½	204
A1.	Gray fine-grained, even-bedded limestone	204	..	204

Fossils may be found in the Jacksonburg at many other localities in the county, but the collecting is for the most part poor, and specific identification extremely uncertain due to distortion of the forms. The fauna of the formation at its type locality in New Jersey contains many more species. Weller[92] lists 64 species, which are divisible into three faunal zones. The lower or *Leperditia fabulites* zone was correlated with the Black River, the two higher zones with the Trenton.

Thickness.—The Jacksonburg formation varies greatly in thickness in Northampton County. Maximum thicknesses are attained along the central and western part of the main Jacksonburg belt in the vicinity of Nazareth, Bath and Northampton. In the quarry of the Nazareth Cement Co. a thickness of 664 feet was measured without either the base or the top of the formation exposed. Of this the lower 360 feet belong to the cement limestone facies and the upper 304 feet to the cement rock facies. This section is crossed by an obscure fault, but the movement seems to have resulted in omission of beds rather than repetition.

[92] Weller, Stuart, The Paleozoic Faunas—Report on Paleontology: New Jersey Geol. Survey, vol. 3, 1903.

It is probable that the total thickness in the vicinity of Nazareth is not less than 700 feet. In the quarry of the Lawrence Portland Cement Co., in the borough of Northampton, 365 feet of beds are exposed in a vertical face, all in the upper cement rock facies. No reliable estimate can be made of the thickness of the lower part of the formation south of Northampton because of incomplete exposures, folding, and a fault contact with the Beekmantown. However, there is no evidence of any decrease in thickness from that estimated at Nazareth.

Eastward from Nazareth, the formation decreases gradually with the minimum for the main Jacksonburg belt occurring along the Delaware River. From Martins Creek to the Delaware, the Jacksonburg crops out in so few places and is so inconspicuous that early geologic maps did not record it. However, isolated exposures definitely establish its presence at several places along this stretch and there is no reason to believe it is not ubiquitous in a narrow belt near the foot of the Martinsburg shale hills, although largely concealed by Delaware River terrace gravels. An estimate based on measurements nearby at Belvidere and Sarepta, New Jersey, would make the probable thickness at the Delaware River about 200 feet.

The narrow belt of Jacksonburg near Portland is even thinner. The section measured there shows a thickness for the entire formation of 108 feet, with a probable error of 20 feet.

The Jacksonburg formation is thinnest in the northeastern corner of the county, where it is about 100 feet thick. It increases in thickness southward, and along the main belt it also increases in a west-southwest direction to a maximum of not less than 700 feet. This increase is due largely to the more argillaceous character of the formation in southern localities, but perhaps in part to the addition of younger beds.

Name and correlation.—Various names have been applied to the Jacksonburg by earlier workers, beginning with Henry D. Roger's "Geology of Pennsylvania, 1858." Rogers referred to the dark shaly limestone as the "Matinal Argillaceous Limestone," noting its probable equivalence to the Trenton limestones of New York State. Frederic Prime in the Northampton County report of the Second Geological Survey of Pennsylvania, 1883, and in subsequent publications of the Second Survey, calls it the Trenton limestone. In 1909, E. T. Wherry[93] divided Prime's Trenton formation into two formations. The lower, called the Nisky formation, would correspond approximately to the cement limestone facies of this report. He correlated this

[93] Wherry E. T., The Early Paleozoics of the Lehigh Valley District, Pa.: Science, new series, vol. 30, p. 416, 1909.

with the Black River of New York. He named the argillaceous limestone (the cement rock facies) the Nazareth formation, and correlated it with the Trenton. B. L. Miller followed Wherry's usage in a report on "The Mineral Pigments of Pennsylvania" in 1911.

In the same year Frederick Peck[94] used the name Nazareth limestone for approximately the same beds Wherry had called Nisky formation, and proposed the new name Lehigh limestone for Wherry's Nazareth formation. B. L. Miller in 1925 correlated these beds, formerly referred to two formations, with the Jacksonburg formation of New Jersey, a name proposed by Kümmel in 1908[95]. Kümmel's type locality is at the village of Jacksonburg near Blairstown in northwest New Jersey, where Weller measured the section and described the fauna in 1903. The name Jacksonburg has been in common usage since then, and includes both the cement limestone and cement rock facies.

The writer[96] in 1937 correlated the type section of the Jacksonburg in New Jersey with the Rockland, Hull and Sherman Fall, the three lowest formations of the Trenton standard column.

Mohawkian standard column

TRENTON	Gloucester Collingwood Cobourg Sherman Fall Hull Rockland
BLACK RIVER	Chaumont Lowville Pamelia

He concluded that the lowest Jacksonburg of New Jersey is probably of Rockland age rather than the equivalent of the Black River as formerly assumed. In Northampton County the Rockland (*Leperditia*) beds are present only in the northernmost Jacksonburg exposure at Portland. Elsewhere in the county the basal Jacksonburg seems to be lower Hull and the top of the formation to lie within Sherman Fall time. Along the main Jacksonburg belt the cement limestone facies covers Hull and lower Sherman Fall time, the more argillaceous facies lying entirely within the Sherman Fall and interfingering with the cement limestone.

[94] Peck, Frederick B., Preliminary Report on the Talc and Serpentine of Northampton County and the Portland Cement Materials of the Lehigh District: Pennsylvania Topog. and Geol. Survey Rept. No. 5, 1911.
[95] Spencer, A. C., and others, U. S. Geol. Survey. Geol. Atlas, Franklin Furnace folio (No. 161), 1908.
[96] Miller, R. L., Stratigraphy of the Jacksonburg Limestone: Geol. Soc. Am. Bull., vol. 48, 1937, pp. 1687-1718.

Stratigraphic relations.—The Jacksonburg formation disconformably overlies the Cambro-Ordovician dolomitic limestones. In parts of New Jersey it is believed to rest on Upper Cambrian beds, the Beekmantown having been completely removed by erosion. In Northampton County, however, the Beekmantown is everywhere present beneath the basal Jacksonburg. The erosion interval between the two formations includes Chazy, Black River and Rockland time. Small angular pebbles of the underlying dolomitic limestones are frequent in the lowest beds of the Jacksonburg, but this conglomerate phase does not normally exceed five feet in thickness, as contrasted with the coarse fifty-foot basal conglomerate at some localities in New Jersey.

Only one visible normal contact of the Jacksonburg and the Beekmantown is known in Northampton County. This occurs in the quarry of the Trumbower Crushed Rock Co. one mile east of Nazareth on the road to Tatamy. Here the basal beds of the Jacksonburg are not fossiliferous. They rest on the Beekmantown disconformably, in one place containing angular pebbles and cobbles of the Beekmantown. Only a few feet away, however, no conglomerate is developed, and the contact is so obscure that it is recognized with difficulty.

A fault contact of the Beekmantown and cement rock facies of the Jacksonburg is visible in the quarry of the Lehigh Portland Cement Co. at Sandts Eddy on the Delaware, but this supplies no stratigraphic information. It is apparent, however, from the Trumbower quarry and from exposures outside the county, to the east, west and south, that a long erosion interval occurred between the end of Beekmantown time and the deposition of the first Jacksonburg beds. The amount of erosion of the Beekmantown is large in New Jersey but becomes progressively less along the contact westward across Northampton County. In Lehigh County the hiatus is still present but practically no erosion of the Beekmantown occurred.

A disconformity exists within the Jacksonburg in the northern belt near Portland. Here the lowest forty-seven feet of the formation are believed to be of Rockland age (see section, pp. 255-256). The next overlying bed of Hull age contains small conglomeratic pebbles, showing a retreat and readvance of the sea. Nowhere else in the county are beds of Rockland age known to exist, so that the Hull lies directly on the Beekmantown.

In earlier reports it has been stated that the Jacksonburg argillaceous limestones grade upward into the Martinsburg shales without a break, but no exposures of the contact had been seen. Discovery of several localities where the two formations are in juxtaposition makes it clear that such is not the case. The Martinsburg shales un-

conformably overlie the Jacksonburg. An angular relation of fifteen degrees was measured near Fogelsville in Lehigh County[97], but most of the normal contacts between the two formations show a near parallelism. The cement rock facies of the Jacksonburg remains calcareous to the highest beds, and the lowest Martinsburg is pure shale. A sharp break is present at every locality in Pennsylvania and New Jersey where the contact has been seen.

In Northampton County, the Martinsburg may be seen overlying the Jacksonburg along Mud Run, one and one-half miles west of Martins Creek. Along the road paralleling the creek a small pit shows the Martinsburg resting on the Jacksonburg with angular unconformity. At creek level there is angular divergence at one place but parallelism a short distance up the bank. There can be no doubt of the presence of an unconformity here, but the hill slope is so steep that creep in the nearly solid Martinsburg beds might plausibly be invoked to explain the angular divergence.

The only other visible contact in the county is explicable by a fault. This exposure lies part way up the bluff on the west bank of Bushkill Creek one mile northwest of Stockertown. A small prospect tunnel driven in the cement rock beds directly beneath the Martinsburg, exposes very perfectly the slickensided undersurface of the shales. Movement was probably not extensive, but the angular divergence here observed cannot be attributed to unconformity in view of the known faulting.

The sequence of events in Lower Ordovician time for the Northampton County region may be summarized as follows: Near the end of Beekmantown time uplift occurred and the seas withdrew from the area. The uplift was greatest in the southeastern part of the county, resulting in considerable erosion of the Beekmantown, but farther west the land was low lying, and basal Jacksonburg was deposited on a nearly undissected Beekmantown surface. The hiatus covered all of Chazy and Black River time.

In early Trenton time (Rockland) the seas advanced over northern New Jersey, depositing high-grade non-dolomitic limestones in northern New Jersey. This sea covered only the eastern edge of Northampton County, the central and western areas remaining as land. A retreat of the Rockland sea was followed by a readvance in early Hull time, and deposition was continuous over the whole county during Hull and early Sherman Fall time. The lower Hull limestones deposited in the southern part of the county (cement limestone facies) are more argillaceous and consequently thicker than those to the north. Beginning in early Sherman Fall time muds were swept into the sea

[97] Miller, R. L., op. cit., p. 1714.

from the south (cement rock facies), overlapping the high-lime facies and resulting in a greatly thickened section of argillaceous limestones of Sherman Fall age. This invasion of clastics had not progressed as far northward as Portland before the sea waters were completely withdrawn. As a result the Jacksonburg there is entirely high-grade limestone.

The post-Jacksonburg retreat of the sea probably occurred within Sherman Fall time, although lack of fossils makes the exact dating difficult. There must have been some warping of the land before the Martinsburg sea readvanced, as the lowest Martinsburg shales seem in some places to have been deposited across the eroded edges of the Jacksonburg.

Local details.—Small variations in the character of the Jacksonburg occur from place to place in the county but in general the two facies are remarkably uniform. In the quarry of the Universal Atlas Cement Co., a drill hole located a short distance southeast of the company office started in cement rock at the surface, which had a calcium carbonate content varying between 58 and 72 percent. At a depth of 200 feet the $CaCO_3$ dropped abruptly to 38 percent and decreased irregularly to a depth of 245 feet. Here another decrease in $CaCO_3$ occurred and 125 feet of shale was pierced before the drilling ceased. The clay content of this shale was continuously over 90 percent. No other place is known where any pure shale occurs in the Jacksonburg, and the cement rock rarely falls below 50 percent $CaCO_3$. The site of the drilling is not far north of a fault which brings the cement rock facies (upper Jacksonburg) against the Beekmantown. The possibility exists that Martinsburg shale may have been downdropped and then overridden by a thrust fault so that none appears at the surface. Unless more drilling information becomes available it seems impossible to decide whether this is the case or whether the shale beds represent an unusual facies of the Jacksonburg.

Martinsburg Formation*

By Benjamin L. Miller and Charles H. Behre, Jr.

Distribution.—The distribution of the Martinsburg in Northampton County is easily described. It occupies the entire northern portion of the county. The southern boundary is an irregular line that passes a short distance north of the boroughs of Northampton, Bath, Nazareth, Stockertown, Martins Creek and Riverton. The northern boundary, therefore, is Kittatinny (Blue) Mountain. One small isolated patch has been noted about one mile southwest of Green Pond. There are similar detached areas at Limeport, Lehigh County and southeast of Springtown, Bucks County.

Lithologic characteristics.—"For practical purposes, the formation is best subdivided on a lithologic basis into a lower, a middle, and an upper part. The lower part is characteristically a banded clay slate, though there are also thin sandstone beds. The middle member contains sandy beds as its most typical facies, though some truly slaty beds are also found in it. The uppermost member is banded like the lower, but there is less sand and the individual beds are much thicker. The differences between these subdivisions are relative and in areal mapping the line between them is drawn with difficulty.

"Judging from his detailed work in southern Pennsylvania and from reconnaissance studies in the region here discussed, Stose has interpreted the Martinsburg as comprising only two distinct members —a lower shaly and an upper sandy one—and regards the uppermost, banded, slaty member of Behre as the lowest member repeated by folding. His viewpoint is well supported by field data, but the difference is chiefly one of structural interpretation and hinges upon evidence not as yet available, so that a final settlement is not possible at present. The structural interpretation of Stose is well set forth in a recent publication[98] and that of the writer is given in the maps, structural sections, and local descriptions of this report. Though of scientific interest, the differences in viewpoint are not of much practical

* The senior author began his study of the Martinsburg deposits of Northampton County in 1907 and was later joined by Dr. Edgar T. Wherry. In 1923, Dr. Charles H. Behre, Jr., then a member of the geological staff of Lehigh University, began detailed investigation of the slates of Northampton County under the auspices of this Survey. His report was published in 1927. A fire that destroyed the bulk of the volumes necessitated a republication, and Dr. Behre re-investigated the slates of this region and extended his work to include the slates of the entire State of Pennsylvania. This enlarged report was issued in 1933. The major portion (all quotations unless otherwise credited) of this discussion is taken literally from Dr. Behre's report with only such additions and modifications as necessary for conformity with the other chapters of this volume. For fuller descriptions and discussion of details, which limitation of space prevents being considered here, the reader is referred to Dr. Behre's publications (See bibliography).

[98] Stose, G. W., Unconformity at the base of the Silurian in Southeastern Pennsylvania: Geol. Soc. Am. Bull., vol. 41, pp. 629-657, 1930.

importance; further reference is made to them on later pages. If the reader accepts the interpretation of Stose, he should read 'lower' where in this report the 'uppermost' member of the Martinsburg is referred to."

"*Lower Martinsburg member.*—The lower member is generally a thin-bedded clay slate or shale. Its prevailing colors are blue-gray or dark silvery gray near the 'neutral gray k' of Ridgeway's color chart, weathering to light yellowish-brown or buff. It contains layers that are alternately siliceous, sericitic or carbonaceous; the resulting banded character is the distinguishing feature of this part of the formation. This banding is shown on the fresh cleavage surface by streaks that are more silvery where siliceous, and grade more toward a black where carbonaceous. Individual beds are generally two or three inches or less in thickness, and never exceed a foot. Workable slate beds are not found throughout the lower Martinsburg, but occur only at certain horizons. Some good banded slate has been quarried with profit in parts of Northampton County, as at Chapman and near Belfast, but it is not extensively worked except at the places named."

No discussion of the lower member of the Martinsburg is complete without descriptions of limestones cropping out within the area of Martinsburg shales in the vicinity of Seemsville. Prime showed these limestones in his 1878 map and again in the 1883 map[99]. The senior author represented them in a generalized geologic map of the Allentown quadrangle.[100]. Stose and Jonas[1] briefly mention these same occurrences. The writer and Dr. Behre re-mapped and enlarged the areas during Behre's investigations of the slate resources. Recently Ralph L. Miller has discussed[2] these same limestones.

Stose and Jonas suggest that these limestones belong to the Allentown formation and have been brought to the surface in an anticlinal fold. More recently Stose has mapped[3] them as part of the Jacksonburg (Leesport?). With the reference of these limestones to the Allentown, Jacksonburg and Martinsburg by different workers, it is important to consider the evidence.

These limestones appear in several isolated exposures. In our revised mapping the areas are extended to include some lowlands without any exposure of rock in place. In these areas there are many irregular masses of vein quartz, up to six feet or more in diameter.

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[99] Lesley, J. P., Prime, F., Atlas to accompany D3, vols. I and II, Pennsylvania Second Geol. Survey, 1883.

[100] Miller, B. L., Allentown Quadrangle, Mineral Resources: Pennsylvania Topog. and Geol. Survey, 1925.

[1] Stose, G. W., and Jonas, A. I., Ordovician Shale and Associated Lava in Southeastern Pennsylvania: Geol. Soc. Am. Bull., vol. 38, pp. 513, 1927.

[2] Miller, R. L., Martinsburg Limestones in Eastern Pennsylvania: Geol. Soc. Am. Bull., vol. 48, pp. 93-112, 2034-2037, 1937.

[3] Stose, G. W., Geol. Soc. Am. Bull., vol. 48, pp. 2032-2034.

These are taken as indication of limestone, since it appears that openings developed at the contact of the massive resistant limestone and the adjoining weak shales during folding and these cavities were filled with quartz. As the rock matrix wore away, these quartz masses have been left on the surface.

The interbedded laminated limestones that R. L. Miller has described in Berks County are not present in this region. Instead, these limestones under discussion are massive dolomitic limestones.

In one locality, about one mile southeast of Seemsville, the limestone is overlain by distinct Martinsburg shales with apparent conformity. At one corner of the quarry the limestones do not seem to be definitely conformable but this is probably due to minor faulting. In this quarry a few beds are thinly laminated and low in magnesia although nearly all the limestone exposed is highly magnesian.

One layer was observed in a quarry along Catasauqua Creek a little over a mile northeast of Howertown that contains some doubtful specimens of *Cryptozoa*. Since *Cryptozoa* are in this region otherwise confined to the Allentown formation, this occurrence does not prevent one from accepting these limestones as of Martinsburg age since in other regions *Cryptozoa* are found in younger rocks.

Another feature that is noticeable in several places is the strongly fetid odor emitted when these limestones are struck. This property is by no means restricted to them but it appears to be more common.

The writer, and also Behre and R. L. Miller, regard these limestones as interbedded with the Martinsburg shales because of their lithologic and chemical dissimilarity to any of the other limestones of the valley. An additional reason for this reference is the positive presence of Martinsburg limestones west of this region. Interbedding seems also to be the explanation for outcrops of the limestone in the bed of a small western tributary of Catasauqua Creek with shale outcrops in the creek bed short distances above and below. No actual contacts are exposed. The absence of any exposure showing shales underlying these limestones and the considerable thickness developed in such restricted areas suggest other explanations than the one offered here but do not disprove our accepted reference.

Stose in a recently published discussion,[4] draws the Martinsburg-Jacksonburg boundary line differently than the one shown on our map and throws all of these limestone areas within the Jacksonburg. In two places some shifting of our line might be made without objection since there are no outcrops to guide one in placing the line at any particular point. The inclusion of these limestones within the Jacksonburg cannot be accepted as there is no rock of similar character

[4] Stose, G. W., op. cit.

within that formation anywhere within Northampton and Lehigh counties and only a short distance away across the strike the Jacksonburg is present in its normal character.

Against reference of these limestones to the Allentown in an unconformable or faulted contact with the Martinsburg shales as suggested earlier by Stose and Jonas, R. L. Miller[5] has advanced the following arguments:

> One small limestone exposure, located along Catasauqua Creek 0.9 mile N70E of Howerton, lies only 200 yards north of the southern margin of the shale belt. Several others are but little farther away. If unconformity be postulated, it would require that 600 feet of Jacksonburg and 1200 feet of Beakmantown thin out, either by non-deposition or by subsequent erosion, in a horizontal distance of 600 feet. This seems impossible.
>
> If faulting be invoked, it would be very difficult to devise any scheme of faults that would bring at least six small blocks of Upper Cambrian into the observed relations with the shales. When one considers that this must happen at six places without leaving at the surface any of the intervening 600 feet of very distinctive Jacksonburg limestone, or the 1,200 feet of less distinctive Beekmantown limestone, the difficulties involved in a fault interpretation become great.

"*Middle Martinsburg member.*—The middle member of the Martinsburg formation is generally composed of two types of rock,—(1) blue-gray banded and commonly sandy shales, resembling in general the more sandy layers of the lower Martinsburg and (2) fine to coarse arkosic sandstones, almost always very impure with shale or lime admixture, and locally bearing pebbles which vary in diameter all the way up to one inch. In a few places the shaly beds of the middle Martinsburg have been sufficiently compressed to yield slaty cleavage, but none of the quarries where attempts were made to work this rock as slate is operating at present, and it is not believed to be a promising horizon for slate making under the existing conditions in the industry."

"*Upper Martinsburg member.*—As stated on a previous page, the rocks here mapped as the uppermost member are regarded by Stose as the lowest member of the Martinsburg repeated by folding and differing from the latter because they have suffered less metamorphism. As Stose's interpretation is not established, and as the lithologic and structural evidence seems to the writer to oppose it, they are treated here as a separate member.

"This part of the Martinsburg formation, commonly called the 'soft' slate, consists of three facies,—(1) beds of blue-gray, very sandy, almost quartzitic slate, in many places approximately a medium-coarse sandstone with calcareous cement, (2) blue-gray sericitic slate—the dominant rock type of this member—with occasional rare chloritic beds, and (3) dark gray or virtually black, highly carbon-

[5] Op. cit., p. 109.

aceous beds, referred to popularly as 'ribbons.' These types of sediment generally alternate in a definite order,—a sandy bed below, followed in turn by a sericitic and then by a carbonaceous layer, though one of these may be omitted. Alternation of these facies gives a banded effect like that in the 'hard' slate or lower member of the Martinsburg, except that individual layers are thicker. Thus, in the lower Martinsburg single beds seldom exceed six inches in thickness, whereas in the 'soft' slate, or upper Martinsburg, beds up to five feet thick are very common, and thicknesses of as much as fifteen feet occur.

"Relative thicknesses of a series of beds are sufficiently distinct to make an accurate correlation over appreciable distances possible.

"Two beds of greenish-gray chloritic slate are sufficiently continuous to serve as horizon markers. They evidently represent layers of impure, calcareous and probably also ferruginous mud deposited in the Martinsburg sea. The quarrymen call them 'Gray' beds.

"The sandy beds mentioned as one of the three prominent constituents of the 'soft' slate rarely approach the heavier slate beds in thickness. They present the appearance in minature of the basal sandstone that should be anticipated beneath a shale where the order of sedimentation is that consonant with the renewal of a sedimentary cycle. They are almost invariably followed in deposition by exceptionally thick beds of the lighter-colored phase of slate, as though there were indeed a genetic relation between the two. This relation is shown in the following examples:

Comparison of thickness of slate and sandstone layers

Name of bed	Light gray slate, Inches	Basal sandy bed, Inches
Big bed, Albion-Bangor quarry	60	4
Big bed, Phoenix quarry	58	7
Big bed, Phoenix quarry	50	3
Big bed, New Diamond quarry	98	9
Big bed, Northampton quarry	97	15
Big bed, Northampton quarry	82	31
Middle big bed, Columbia Bangor quarry	121	9
North Bangor No. 3 big bed, Bangor Vein quarry	153	35

"Occasionally, as in the case of the Genuine big bed, Parsons quarry, an alternation of light and dark beds intervenes between the thick light gray and the sandy beds. Again occasionally a thicker 'hard roll' will be followed by an unexpectedly thin bed of light-colored slate. These are, however, exceptions.

"In some instances intraformational unconformities are seen beneath such sandy layers. Frequently also the sandy beds show cross-

bedding and ripple marks, the current generally coming from the east,—a fact which may obviously be used in determining whether beds are in the normal position or inverted.

"The rhythmic sequence of light and dark beds in the slate district has generally attracted the attention of geologists.[6] Careful measurements by the writer have shown that no rule governs the ratios between the thickness of dark beds and succeeding light ones. Barrell thought the normal sequence consisted of very dark beds followed by sandy layers; this he attributed to settling in saline water after storms, the more muddy matter agglutinating before the sands came down. Very probably the cause—that is, differential settling after storms—is correctly divined, but clearly the sequence was purer mud followed by carbonaceous clays—the reverse of Barrell's idea. The most surprising feature is the sharpness of the line separating differing layers. This suggests marine sedimentation.[7]

"Locally in this uppermost member of the Martinsburg formation there are beds of pure calcite, now coarsely crystalline. They are generally very thin, seldom more than half an inch. The quarrymen speak of them as 'silver ribbons' or, when the slate breaks parallel to them, as 'loose ribbons.' Rarely, as in the bottom of the Jackson-Bangor No. 6 quarry at Pen Argyl, have they been minutely fractured. These calcareous laminae are important from the structural viewpoint because movement between beds commonly took place along such 'silver ribbons.' "

Thickness.—Few problems in this region have aroused more discussion than the thickness of the Martinsburg formation. The figures given by different geologists are so widely variant as to indicate inaccurate and careless work to the person unfamiliar with the difficulties encountered. The region has been sharply folded, faulted, eroded, covered by glacial deposits and surficial soils to such an extent that exact measurements are not possible. The similarity of the beds and the absence, particularly in this region, of any guide or key beds that can be positively identified for any considerable distance, are responsible for the present situation. Also there is the problem of three members or two with the lower one repeated. Several workers are now engaged in the study of these vexing questions and are extending their investigations far beyond the confines of a single county so that it is hoped that a satisfactory solution will eventually be forthcoming. Behre's statements are quoted from his extensive report.

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[6] Barrell, Joseph, Rhythms and the Measurements of Geologic Time: Geol. Soc. Am. Bull., vol. 28, pp. 803-804, pl. 43, 1917.

[7] Kindle, E. M., Diagnostic Characteristics of Marine Clastics: Geol. Soc. Am. Bull., vol. 28, pp. 907-908, 1917.

"The exact thickness of the formation is in doubt and there are no places within the region here described where the exposures are sufficiently continuous to yield dependable measurements. Along Delaware River, Sanders estimated the entire Martinsburg to be 5240 feet thick, but says that this 'is more likely an understatement than an exaggeration.'[8] This is the maximum thickness mentioned in any of the reports of the Second Geological Survey of Pennsylvania. Stose regards the thickness as about 3,000 feet. Three sections have been measured in great detail by the writer,—one each along the Delaware and Lehigh rivers and one between the two streams—and the arithmetical average of these measurements is 11,534 feet, though on account of possible repetition through folding, this is probably too high, rather than too low a figure. It is impossible to obtain accurate measurements, yet it would seem that approximations should not be discounted in favor of mere guesses. In general, the thickness in this region may therefore well be taken as about 11,000 feet.

"The thickness of the lowest member of the Martinsburg formation in Lehigh and Northampton counties is about 5000 feet. No sections have been measured farther west, but from the width of outcrop it is assumed that this figure also holds for eastern Berks County.

"The thickness of the middle member in the area here discussed is about 4,200 feet, this being the average of two measurements—one along Little Bushkill Creek and the other along Lehigh River.

"Along the Little Bushkill, in Northampton County, where a poorly exposed section was measured by the writer, the thickness of this member appears to be 4,415 feet, but the exposures here are discontinuous and the measurement may well be vitiated by repetition.

"On the basis of these observations the thickness of the upper Martinsburg in eastern Lehigh and in Northampton counties may be about 2,600 feet."

Paleontologic characteristics.—Fossils are rare in the Martinsburg of Northampton County and where found are almost invariably in a poor state of preservation. In the detailed investigations now in progress in Lehigh and Berks counties and which will be extended into Northampton County, more fossils have been found and it is believed that careful search will yield further results in this region.

"The larger part of the fossils are from coarse, impure sandstone occurring near the top of the middle member. The list, identified by Dr. E. O. Ulrich, includes:

[8] Sanders, R. H., Geology of Lehigh and Northampton Counties: Pennsylvania Second Geol. Survey, D3, vol. 1, p. 85, 1883.

Zygospira modesta
Dalmanella cf. multisecta
Sowerbyella sericea
Hebertella sinuata
Plectorthis cf. plicatella
Rafinesquina aff. camerata
R. cf. alternistriata
R. centrilineata (?)
Strophomena spec. nov.
Sinuites aff. cancellatus
Lophospira aff. obliqua
Tetranota rugosa
Liospira aff. progne
Lepidocoleus jamesi
Aparchites (?) sp.
Ctenobolbina ciliata
Calymene sp.
Proetus sp.
Ctenodonta aff. levata

"A small collection of poorly preserved fossils was made from the sandy beds here mapped as middle Martinsburg, south of Point Phillip (Wind Gap quadrangle), and was referred to E. O. Ulrich, who pronounced them to be older than Pulaski, and probably Trenton in age[9]; but the reference may well be doubted, in view of the poor state of preservation."

Name and correlation.—The geologists of the First Geological Survey of Pennsylvania designated the strata now called Martinsburg as III or Matinal. The Second Geological Survey called them Hudson River, a term that is still used occasionally. During the past twenty-five years the name Martinsburg, from the West Virginia town of that name, has been used by geologists.

Satisfactory correlations await the paleontologic investigations now in progress. Within a few years it is believed that sufficient fossil material may become available for more definite correlations than can be made at present. Tentatively, the lowest member is correlated with the Eden and the middle (upper?) with Pulaski.

Stratigraphic relations.—As discussed by Ralph L. Miller on a previous page, the basal Martinsburg beds rest unconformably upon the Jacksonburg.

In turn, the Martinsburg is overlain unconformably by the Shawangunk (Tuscarora). This relation is shown in only one place within the county. A railroad cut in the east side of Lehigh Gap shows the unconformable relations that everywhere else within the county are concealed by the talus of Kittatinny (Blue) Mountain.

Local details.—Inasmuch as this Survey has previously published two reports (see bibliography) by Behre in which scores of quarries and exposures are described in detail, it seems inadvisable to repeat them here.

SILURIAN SYSTEM

Shawangunk Formation

Distribution.—The Silurian system is represented in eastern and central Pennsylvania by the Shawangunk conglomerates and sand-

[9] Stose, G. W., op. cit., p. 655.

stones that form Kittatinny (Blue) Mountain. The line that separates Northampton County from Carbon and Monroe counties follows the crest of the mountain and throughout is on this formation. This formation occurs nowhere else in Northampton County. The main description of the Shawangunk formation is contained in the chapter by Bradford Willard on the water gaps and wind gaps of the region and, therefore, the discussion here is brief.

Lithologic characteristics.—The Shawangunk deposits are readily distinguishable from those of any of the other formations of the region. They are primarily coarse conglomerates composed of rounded quartz pebbles up to a few inches in diameter firmly cemented by siliceous matter. They are the hardest rocks of the county and the most resistant to erosion. This accounts for the mountain. The beds are mainly massive and joints are few so that huge blocks occur in the talus overlying the Martinsburg shales on the southern slopes of the mountain. Shale pebbles occur in certain beds.

Interbedded with the conglomerates are beds of sandstone and thin layers of black slate.

Paleontologic characteristics.—Some fossils have been found in the formation at the Delaware Water Gap as described in an earlier chapter by Willard. Recently a fucoid or worm trail, *Arthrophycus harlani,* has been found along the highway just south of Little Gap.

Thickness.—Only the lower part of the Shawangunk formation is present in the county and no attempt has been made to determine the exact thickness of this part. C. K. and F. M. Swartz[10] state that the entire formation at Lehigh Gap is 457 feet thick and probably 1,823 feet at the Delaware Water Gap.

Name and correlation.—The formation is named from Shawangunk Mountain in New York, with which Kittatinny Mountain is continuous. To the west the conglomerate forming Kittatinny has been termed the Tuscarora. It appears that the Tuscarora corresponds to the lowest portion of the Shawangunk.

The Second Geological Survey of Pennsylvania used the names Oneida and Medina for these deposits.

The formation is the lowest member of the Silurian period in this section.

Stratigraphic relations.—There is general agreement that the Shawangunk rests unconformably upon the Martinsburg shales. At Lehigh Gap this unconformity can be seen in a cut along the Lehigh & New England Railroad where the Martinsburg shales dipping to the

[10] Geol. Soc. America Bull., vol. 42, pp. 621-662, 1931.

northwest are truncated by the basal beds of the Shawangunk inclined in the same direction but with about thirteen degrees less dip. The basal conglomerate here is iron-stained and disintegrated. Nowhere else in the county has this contact been observed by the writer.

It is of interest to note that J. P. Lesley[11] argued strongly against an unconformity (nonconformity) between these two formations.

If Stose's interpretation of only two members of the Martinsburg instead of three, as favored by Behre and the writer, is accepted, this unconformity becomes of such magnitude that the movements and erosion that separated the two periods of deposition in the region may well deserve the name of the Taconic Revolution instead of the Taconic Disturbance.

Beyond the borders of the county the Shawangunk is conformably overlain by the Bloomsburg red shales.

TRIASSIC PERIOD

Brunswick Formation*

Distribution.—Rocks of Triassic age are well developed in southeastern Pennsylvania in a broad band that sweeps across the State in a general southwesterly course from New Jersey to Maryland. The belt is thirty-two miles wide where it crosses the Delaware River. The Triassic rocks occupy less than one square mile of Northampton County. They constitute Flint Hill, a segment of which extends into the county at the extreme south end. They constitute the major portion of adjoining Bucks County. These rocks are almost everywhere easily distinguished from those of other ages because of fairly uniform lithologic characteristics. They comprise great thicknesses of alternating sandstone and shale, chiefly red or reddish brown but in places black or pale green. In places there are extensive developments of coarse conglomerate.

The Triassic rocks of Pennsylvania and New Jersey have been named the Newark group. It has been subdivided into the Stockton, Lockatong and Brunswick formations. The last-named is the youngest and is the only one present in Northampton County.

Lithologic characteristics.—In its wider distribution the Brunswick is mainly composed of shale and sandstone but that portion included within Northampton County is principally a conglomerate. The pebbles or cobbles, composed mainly of fine-grained white quartzite, are embedded within a matrix of feebly consolidated red mud. The matrix wears away easily and is removed by surface water, leaving the

[11] Pennsylvania Second Geol. Survey, D3, vol. 1, pp. 32-35, 1883.

* On the geologic map the Brunswick boundary in east half of small area should be close to the 520-foot contour line.

ground strewn with the pebbles. These are distinctive in that they have been colored red on the outside by the red coloring matter of the mud matrix and the same stain has penetrated the pebbles along cracks. Some of the cobbles are as much as one foot in diameter and are themselves conglomeratic; most of the cobbles are fine-grained and less than three inches in diameter. They are only fairly well rounded. Some have been broken by frost action into sharp angular fragments.

Where fresh excavations have been made either by stream erosion or artificially, limestone pebbles, usually more angular than the quartzites, are fairly abundant. Near the surface some of these limestone fragments have been entirely removed by erosion, producing a honeycombed rock. A few excavations and a shaft located about three-fourths mile southwest of Leithsville on the east side of a small north-flowing stream, exhibit the character of this conglomerate to excellent advantage. These openings were made in search of a copper deposit. The only evidence of copper was thin films of green malachite coating some of the pebbles, particularly the limestones.

On the east side of a ravine about three-fourths mile southeast of Leithsville about 42 feet of well-consolidated conglomerate rests on 6 feet of hard red sandstone with thin conglomeratic lenses. Beneath is another red sandstone about 3 feet thick that is more conglomeratic. The beds dip about 14° SW. and strike N. 30° W.

There has been considerable discussion concerning the origin of both the limestone and the quartzite cobbles. The quartzites have probably come from the Shawangunk of Kittatinny (Blue) Mountain, although some have suggested the Green Pond conglomerate of New Jersey. The limestone cobbles probably came from the Cambro-Ordovician limestones although the writer has found a much larger percentage of low-magnesian stones than one would expect from the largely high-magnesian limestones adjacent to the region.

Thickness.—The Brunswick formation in its full development is believed to be several thousand feet thick. That portion included within Northampton County is about 300 feet thick.

Name and correlation.—These rocks have been known under several different names. The First Geological Survey of Pennsylvania designated them as the "Mesozoic Red Sandstones." The Second Geological Survey generally called them the "New Red" because of the color and the distinction from the "Old Red" sandstones of the Paleozoic. From the New Jersey geologists we have the general name "Newark" and the names of the subdivisions.

Several different correlations for the deposits of Flint Hill have been suggested. In 1885, the Second Geological Survey of Pennsyl-

vania referred them to the Mesozoic and stated that here occurs "a cemented conglomerate of quartzite and limestone fragments brought by mountain torrents from the once higher lands of Northampton and Lehigh county" (Report X, p. XXIX). Lyman in 1893 referred them to the Chikis (present-day Hardyston) and Wherry in 1909 suggested a correlation with the Shawangunk conglomerate of Kittatinny (Blue) Mountain of Silurian age. At present, however, all geologists agree upon their position in the geologic time scale of Pennsylvania.

Stratigraphic relations.—Within Northampton County the Brunswick deposits rest unconformably on the Tomstown limestone. In adjoining areas they have been deposited upon eroded surfaces of the Hardyston and other formations.

There has been considerable discussion whether the north border of the Triassic throughout Pennsylvania and New Jersey is a fault or an overlap contact. Actual exposures of the contact are rare. The writer believes that in Northampton and Lehigh counties the Brunswick overlaps the Paleozoic formations with which it is in contact. The presence of Triassic cobbles and red soils farther north and in other places than one might expect to result from simple wash seems to furnish evidence of the former greater extension of the deposits.

QUATERNARY SYSTEM

The Pleistocene geology of Northampton County consists of the glacial, alluvial, colluvial and residual deposits. Of these the glacial is of so much greater importance and general interest that it overshadows all the others.

Glacial Deposits

Long before the acceptance of the idea of an invasion of the northeastern part of the United States by an ice sheet, geologists had noted and described the cobbles and boulders that are a common feature of extensive areas. In some instances it was noted that they were lithologically similar to rocks in place at varying distances to the north and northeast. The only explanation proposed was that they had been brought to their present locations by extensive flood waters coming from the north. In Northampton County they were attributed to great floods that occurred when the waters of a supposedly large lake lying to the north of Kittatinny (Blue) Mountain, and impounded by the mountain as a dam, burst the barriers at the Delaware Water Gap and Lehigh Gap and flooded the areas to the south. These torrents of water were believed to have carried and distributed gravels and boulders over almost all parts of the county.

Even before 1850 when Louis Agassiz advanced the idea of a former ice sheet, several other investigators had suggested that the large boulders must have been carried by floating ice cakes or icebergs. Agassiz' hypothesis did not meet with ready acceptance generally although J. P. Lesley states[12] that in 1850-1851 he and Prof. Edward Desor of Switzerland did recognize scratches (striae) on some rocks near Ashland as produced by ice.

Soon after the establishment of the Second Geological Survey of Pennsylvania in 1874 attention was directed to the glacial deposits of this region. Since then many geologists have contributed to the discussion and added valuable data. It does not seem advisable to describe or even list each publication inasmuch as they are included in the Bibliography which forms an earlier chapter in this volume. Attention may be directed to the articles by C. E. Hall (1876), F. Prime, Jr. (1879), J. P. Lesley (1881), G. Frederick Wright (1882, 1889 and 1893), H. C. Lewis (1883, 1884 and 1885), T. C. Chamberlain (1890), Angelo Heilprin (1890), R. D. Salisbury (1892 and 1902), J. Barrell (1893), E. H. Williams, Jr. (1893, 1894, 1898, 1917 and 1920), F. Ward (1929, 1934 and 1938), and F. Leverett (1934). Among these H. Carvill Lewis and E. H. Williams, Jr. deserve special mention. Prof. Williams spent more time and accumulated far more detailed information than any of the other investigators. For years he and groups of his students tramped the region on foot over week ends, holidays and vacations, collecting every bit of information possible. Among these students was Joseph Barrell who later won recognition as one of the ablest and most careful geologists whom this country has produced and whose early death was a distinct loss to American geology. Unfortunately, Prof. Williams' contributions were not written in the best form to convey his ideas to the reader. The writer feels that had he not had the opportunity to go into the field with Prof. Williams on numerous occasions he might never have fully comprehended his points of view. The destruction of all his detailed field notes by fire was a great loss. The writer here wishes to record his sincere appreciation of Prof. Williams and his work.

The writer does not regard himself as a glacial geologist and therefore feels his limitations in preparing this discussion. However, it may prove useful to later investigators to have a summarized description by a person familiar with the region and with many phases of the problem. Having taken a number of glacial geologists to critical places in this region, opportunity has been afforded to learn the different interpretations that have been offered by them. This applies particularly to geologists who have never published their ideas on this region.

[12] Pennsylvania Second Geol. Survey, vol. Z, p. XLI.

One of the most important questions to be considered concerns the number of times the glacial ice advanced into the region. Did the ice push downward one, two or three times from the northeast and come within the present limits of Northampton County? Also, how shall the deposits of this region be correlated with those of the Mississippi Valley, the generally accepted type sections?

The earliest workers in the region recognized only one ice invasion, the one best preserved and most noticeable because of the development of the fine terminal moraine in the Bangor region. This has been correlated with the Wisconsin ice sheet of the Mississippi Valley.

When glaciated cobbles were discovered to the southwest of this morainal belt, they were explained as outwash material carried by the water resulting from the melting of the ice. However, when ice-deposited material, glacial till, was found in these places it was recognized that at some time glacial ice did extend beyond the "terminal moraine." The belt was termed the "glacial fringe," the "attenuated border" or "extra-morainic drift." Prof. Williams searched the Lehigh Valley to determine the extent of this "fringe." He found it to extend as far as the Schuylkill River, near Shoemakersville, Berks County. To this fringe he applied the name Kansan, but used the term in a different sense than do the geologists in the Central States. He believed that the Kansan deposits, as he described them, represented the first advance of the ice sheet in the region and that near its margin it was thin and accomplished little glacial erosion. He also believed that the ice was more fluid near the margin because of the melted ice and that the front receded quickly. When the front had moved back to the Bangor region there was a long halt and the pronounced terminal moraine was built. Williams therefore believed there was but one ice sheet in the region and his "Kansan" designation only meant the farthest and most rapid advance and retreat of the Wisconsin. In places he terms it the First Phase. When he was confronted with the evidence of greater age characteristics of the deposits beyond the "terminal moraine" he replied that it was natural to find these old-age features because the first advance of the ice picked up the weathered material on the surface. He maintained that the finding of a single or a few fresh rock fragments in the "fringe" deposits, materials that seemed as fresh as similar pebbles in the Wisconsin glacial deposits, was sufficient evidence of approximately the same age of the two. He expressed his view in the expression "the time elapsed since drift deposition is measured by the freshest part." In his search he found pebbles which he regarded as fresh as those of the Delaware Water Gap region. He also called attention to the fresh appearance of the slate directly beneath the till of the "attenuated

border'' in different places, particularly in one quarry near Northampton (Siegfried).

In general Prof. Williams' idea of a single ice invasion has not been accepted, although George H. Ashley has recently expressed an interest in this view. The most commonly accepted interpretation is that the glacial deposits of the Bethlehem region belong to a much earlier ice sheet than the Wisconsin. For some time they were referred to the Jerseyan, an older series of deposits described in New Jersey.

When Frank Leverett came into the district and saw the moraines in the Saucon Valley and near Trexlertown in Lehigh County, he concluded that there were two distinct ice invasions before the Wisconsin. He particularly investigated the deposits in the vicinity of Bethlehem and Allentown and decided that they and the moraines mentioned belong to an ice sheet that he termed the Illinoian because of resemblance to the Illinoian of the Mississippi Valley.

The farthest advance of the ice south of the Illinoian moraines for the present is designated as the Jerseyan, which is roughly correlated with the Nebraskan of the Central States.

So far, no occurrences have been found in Northampton County where deposits of two of these sheets are in contact. That also applies to any interglacial beds such as have been described in Iowa and other Central States.

Accepting the belief in three different ice invasions in the Lehigh Valley, the evidence for each one as it is developed in Northampton County will be discussed.

WISCONSIN ICE SHEET

Although geological formations are generally described in order of age, the oldest first, it seems better to reverse that order in the discussion of the successive ice invasions of Northampton County. The marks of the Wisconsin ice sheet are well preserved and in many aspects readily decipherable, whereas those of the earlier sheets are scanty and vague in most places and can best be interpreted after a study of the most recent one.

In this discussion are embodied extensive quotations from an unpublished manuscript by Dr. Henry B. Kümmel entitled ''Report on the Surface Geology of the Delaware Water Gap and Easton Sheets, Pennsylvania.'' The report was prepared in 1896 and based on eight weeks' field work in 1895. In most respects the report is in agreement and well supplements Pennsylvania Geological Survey Bulletin G 10, ''Recent Geological History of the Delaware Valley below the Water Gap'' by Freeman Ward. There are certain disagreements but these mainly are concerned with interpretations. The presentation of di-

verse views seems desirable inasmuch as all geologists are searching for the final correct answers to their problems. In most instances the writer prefers to call attention to the different views without attempting to decide which appear to him as more nearly in harmony with his own views.

Until Ward in 1929 set forth his ideas of the Wisconsin Ice Sheet, all glacial geologists were in agreement that the terminal moraine enters Pennsylvania a short distance below Belvidere (or Riverton) and leaves Northampton County by crossing Kittatinny (Blue) Mountain into Monroe County a short distance northeast of the Little Offset. Ward claims that the Wisconsin ice does not cross Kittatinny (Blue) Mountain in Pennsylvania nor does it cross the Delaware River near Riverton. Instead, it sends a narrow lobe down the Delaware Valley as far as Carpentersville, N. J. (opposite Raubsville, Pa.). He presents detailed evidence in his articles (see Bibliography) which must be consulted. Briefly, he claims that the drift and glacial striae on top of the mountain belong to the Illinoian ice sheet on the basis of evidence of greater age, and the drift at Carpentersville, referred to the Older Drift by Salisbury and others, belongs to the Wisconsin on the evidence of more recent age.

Extracts from an unpublished manuscript by Henry B. Kümmel follow.

The Moraine.

The terminal moraine crosses the Delaware River a mile and a half south of Belvidere, N. J. at Foul Rift, where the river has an elevation of 220 feet A. T. For a short distance the moraine lies in the valley of the river, but it soon rises to an elevation of a little over 600 feet on the Slate Hills, which bound the river valley. It crosses these in a generally westward direction for five miles or more to Martin's Creek at elevations varying from 400 to 809 feet. This latter elevation is reached a mile and three-quarters north of Mt. Pleasant. From the valley of Martin's Creek at Nazareth Junction, the moraine extends northwest through Factoryville and Ackermanville. Its continuity is here somewhat broken by stratified deposits along the line of Waltz Creek, which joins Martin's Creek, below Factoryville. From Ackermanville it extends northward, as a well marked belt averaging over a mile in width. Its outer margin lies not far east of the Plainfield-Washington township line and is in general sharply defined. The inner margin passes through Bangor, the western part of the town being built amid hummocks and hollows of the moraine. As the moraine approaches the foot of Kittatinny Mountain it turns a little to the east and skirts the base of the ridge as far as "The little Offset" constantly attaining however, a greater elevation. Between Little Offset and Fox Gap, it makes a sharp turn to the west and crosses the high ridge of Shawangunk sandstone at an elevation of over 1560 feet and descends the back slope of the mountain towards Kemmererville. The drift is thick upon the narrow crest of the ridge where the moraine crosses it, and the morainic topography is slightly developed. Here in 1894 clearings were made on the top of the mountain, the only attempt for miles in either direction to cultivate the barren summit. On the almost precipitous southeastern or front face of the ridge the morainic topography is wanting, and there is but little drift. Neither could the characteristic morainic topography be made out in the

thick undergrowth on the back of the mountain, until the clearings on the lower slopes of the mountain near Kemmererville were reached.

Near Fox Gap, as already described, the main moraine crosses the Kittatinny Mountain, but another belt of morainic topography extends northeast from the Gap along the foot of the mountain for a distance of three miles, reaching to within about a mile of the Delaware. This morainic belt is in the nature of an interlobate moraine, formed between the lobes of ice which occupied this part of the Kittatinny Valley and valleys of Cherry Creek and Pocono Creek on the further side of Kittatinny Mountain. From the map it will be seen that the ice projected about six miles further southwest along the axis of Kittatinny Valley than it did upon the high ridges on either side.

The length of the moraine, as thus traced, is about twenty miles. Its elevation varies from something less than 300 feet where it crosses the Delaware River to something more than 1560 feet on the crest of Kittatinny Mountain. For about fourteen miles of the twenty, it crosses the rolling slate hills of Kittatinny Valley, a much dissected peneplane with a general elevation of from 600 to 700 feet, but trenched by narrow valleys sunk 250 to 350 feet below the older denudation surface. The vertical range of the moraine within the area described is over 1200 feet, and it ascends hills and descends valleys almost independently of the topography.

The breadth of the moraine belt varies from but little more than a quarter of a mile to a mile and a half. Between Martin's Creek and the Delaware River the average width is a little over one-half mile. From Ackermanville north to Kittatinny Mountain its breadth averages more than a mile.

The topography. The characteristic morainic topography is on the whole well developed and in general the morainic belt is strongly marked and sharply distinct. Locally, however, this is not the case. On the low ground near the Delaware the morainic topography is strongly marked along the inner margin, where knolls and short winding ridges, surrounding and more or less completely inclosing irregular shaped kettles, rise fifteen to twenty feet above their surroundings. Here the moraine rises 100 feet above the level of the Delaware gravel terraces to the north, but only twenty feet above the overwash valley-train to the southward and forms a predominant topographic feature when viewed from the north. Towards the outer margin the morainic topography is gradually lost as the moraine passes into the river deposits. A fine view of the morainic topography in the valley can be had from the Gravel Hill school-house, halfway up the slate hill to the north.

On the slope from the valley bottom to the general slate upland, the morainic topography is not strong, but it is again well marked upon the broad upland surface. Westward to Nazareth Junction it is in general easily recognizable even where the belt is narrowest. The knolls although not as large and massive are well marked and their association with shallow undrained depressions is typical.

West and northwest of Bangor as far as Fox Gap, the moraine is developed in great strength. The vertical relief is not infrequently thirty or forty or even sixty feet and the confused assemblage of conical hills, ridges, and hollows is finely shown. Large boulders are common upon the surface. Due west of Bangor the moraine is locally bordered by a small overwash plain. Viewed from this plain the outer margin of the moraine appears as a ridge rising abruptly forty to sixty feet above the plain level. The moraine is probably nowhere better developed; nowhere more massive, nor characterized by more sharply marked hummocks, ridges and kettles than between this point and where it ascends the mountain face near Fox Gap. A fine view of the wooded knolls of the moraine, as it bends around the end of Little Offset can be had from the slate hills north of East Bangor.

The material. In the Delaware Valley much of the material of the moraine is poorly assorted sand and gravel, but till is by no means absent. On the higher ground of the slate hills the moraine is composed almost

entirely of firm, tough, clayey till with an abundant admixture of stones and boulders. Between Factoryville and Ackermanville, where the moraine lies in the valley of Waltz Creek, there is considerable sand and gravel, but further north it is again almost entirely of till, closely set with stones of all sizes up to boulders, occasionally twenty feet in diameter. A considerable proportion of the boulders are striated and a very large proportion are distinctly glaciated and worn. Probably 56-60 per cent of them are from the Shawangunk formation. Slates, sandstones, shales, greywacke and limestones are more or less abundant and of various kinds. The Martinsburg formation has contributed quite largely, and some large boulders of Caudi Galli grits were identified by the fossils. The bulk of the sandstones, shales and greywacke probably come from the Shawangunk, Hamilton and overlying formations and were transported across the Kittatinny Mountain. Limestones from the Lower Helderberg and from the Onondaga rocks north of the mountain also occur, and a few Oriskany sandstones were noted. A few small specimens of an igneous rock closely resembling the New Jersey Beemerville Elaeolite Syenite were found. As would be supposed from the scarcity of limestone boulders in the moraine, the till is not strongly calcareous, and rarely could any calcareous content be detected even far below the depth to which oxidation and weathering had penetrated. Locally the till of the moraine is highly calcareous. This coloration resulting from oxidation has in general penetrated only four to six feet; below this depth and not uncommonly at a less depth, the till is buff or light gray in color and fresh in appearance. The bowlders upon the surface are in general fresh in appearance and not deeply weathered. The weathered zone varies in thickness from a 1/32 of an inch to an inch or in rare cases more, according to the character of the rock. Some of the small limestone boulders were merely honey-comb masses of chert or flint, the limestone proper having been dissolved. In spite, however, of a few cases of great disintegration, such as these, the general aspect both of the till and of the boulders on the surface, is of youth and freshness. Some of the boulders and cobbles are more deeply weathered on one face than on the others, or the weathering may be uniform in depth on all sides but one, where it is much less. In many respects these have the appearance of cobbles deeply weathered in pre-morainic time and freshened by later glaciation. These freshened cores were more abundant among the Shawangunk boulders than any others.

The Till. With the exception of the low ground along a few of the larger streams, the area north of the moraine is quite generally covered by a sheet of till of varying thickness.

In its larger features the topography of the slate belt north of the moraine is not unlike that of the extra-morainic shale hills. The till sheet is not thick enough to greatly change the topography. This statement is less applicable to the northwestern side of the valley than to the southeastern, but in both regions it is in general true. On the other hand the peculiar undulatory shale-knoll topography so marked in Sussex County, New Jersey, is not in general developed here. In general the till is so evenly distributed as to cover the rock, even though locally the covering is very thin. On some of the steepest slopes of the hills near the Delaware and its tributaries, the soil is chiefly residuary, but these areas are small and unimportant. The till by no means forms a sheet of equal thickness. In many cases it varies greatly within comparatively short distances, particularly on the hillsides. The chief effect, therefore, of the till in changing the topography is in changing the steepness of the slopes—usually in the direction of a more gentle gradient. In many cases the preglacial valleys have been partially filled—never completely save toward their heads where they were very shallow. The amount of vertical relief is not, therefore, on the whole quite so great as in preglacial times and as in the corresponding extra-morainic regions, although the general features of the topography are not markedly changed.

The thickness. The greatest known thickness is sixty to seventy feet, where it is exposed over an abandoned quarry west of Slateford. This thickness of drift is not all till, as layers of sand and gravel of considerable

extent are interbedded in the section. Over many of the slate quarries near Bangor the till is from five to thirty feet thick, these limits being seen in the same quarry. Along the roads the till is frequently seen to exceed six feet in thickness, but not uncommonly, particularly in southeastern Upper Mount Bethel township, rock is reached at depths of three, four or five feet. Perhaps seven or eight feet would be a fair average for the depth of till in the southeastern part, and a somewhat greater depth nearer the mountain.

Character. The till of this area is not markedly different from the till of the moraine. It is slightly less bouldery and more clayey, but the difference is not conspicuous. Although less bouldery than the moraine, stone of all sizes are extremely abundant. The common constituents are those already mentioned as occurring in the moraine. Shawangunk quartzites and conglomerates are everywhere the most abundant, but there are large numbers of gray sandstones and slates, probably from several horizons; Martinsburg, Caudi Galli, Hamilton and others. Red sandstones from the Shawangunk and probably from the Pocono are common. Helderberg and Onondaga limestones and Oriskany sandstones also occur, but sparingly. Several bowlders of the Onondaga ten and eighteen feet in diameter occur about three-quarters of a mile west of Slateford.

Striæ are common on the softer slates and sandstones, and more rare on the hard Shawangunk quartzites. Planation surfaces are much more abundant and chatter marks are not rare. In general the till is weathered to a depth of less than five or six feet, but the lime content is small even in unoxidized till. Most of the boulders have been but slightly affected by the weather in their present positions, but not a few were found unequally weathered on different sides and give evidence in themselves of being freshened rock cores.

A few small localities occur within the moraine, in which all the boulders have taken on a dark yellowish-brown approaching in cases a chocolate-brown color. This deep coloration gives them an appearance of great age. and it has been one of the reasons for asserting the great age of the extra-morainic drift whose boulders are so uniformly of this color. The areas within the moraine in which these dark brown boulders occur are *always* areas of poor drainage, where the boulders have lain on soggy ground. Such conditions seem to favor somewhat rapid discoloration.

In the case of the extra-morainic drift, no such distinction prevailed. The brown-colored boulders occur on high and well-drained areas as well as in wet places, and the inference is that long exposure brings about the same changes.

Relationship of the till to underlying rock. In by far the greater number of quarries the till is seen to rest upon the broken and disintegrated shale and slate. In some instances the till grades into broken shale in a manner which indicates that the ice kneaded the upper part of the residuary material, incorporated a small amount of foreign material, and then covered the whole with a layer of tough clayey till composed largely of foreign material. In a few instances the till was found to rest upon the worn and polished rock. It cannot be assumed that the shale had disintegrated after the drift covered it, for several reasons. First. Only the upper three or four feet of the drift have been oxidized and that overlying the broken shale is fresh. Second. The fact that striæ on many ledges which have been but slightly protected are still fresh and clear cut shows that the weather has had but small effect upon the slate in post-glacial time.

The inference which would most naturally be drawn from the relationship of the till to the disintegrated shale in these quarries is that the ice possessed but little erosive power. Certainly it did but very little eroding over quite wide areas in this region.

Kittatinny Mountain. On Kittatinny Mountain the till is in general rather thin. The steep southeastern escarpment is bare of drift and at its foot lies a steep rocky talus. On the top and back of the mountain there

is a mantle of bouldery till composed largely of local material. Outcrops of rock are very abundant and numerous striated surfaces were found. The striæ vary in direction from S. 5 W. to S. 58 W. (magnetic), the average direction being S. 30 W.

Johnsonville-Portland Kame Area. A kame area of considerable extent occurs along Jacoby Creek, southwest of Portland. The creek rises near Johnsonville and flows northeast into the Delaware River. The gravel deposits, however, form the divide about Johnsonville, separating this stream from a small tributary to Martin's Creek, and occur for a short distance along this latter stream, where they form low terraces and inconspicuous kames bordering a swamp, the site of which seems to have been occupied by the ice when the gravel was deposited. In the vicinity of Johnsonville the deposits form a gently undulatory plain, whose surface is quite till-like, although excavations show stratified material. The elevation of this plain is about 500 ± feet. Midway between Johnsonville and Portland the kame-like character of the area is best developed. Massive knolls of loose sand and gravel, with cobble-strewn surfaces rise thirty to forty feet above the hollows between them. On their flanks are smaller knolls. Locally the hillocks give place to small plains or terraces. Kame knolls are well developed just west of Portland, the school house of the village being situated upon one of the largest individual hillocks.

Esker. About a mile and a half southwest of Portland in the midst of the kame knolls there is a narrow winding ridge, so sharply defined and so continuous as to deserve the name esker. Its length is nearly three-fourths of a mile. It is hardly more than twenty feet wide on the crest, which is gently undulatory and increases in elevation to the southwest. Locally it rises forty feet above its surroundings. Towards its southwestern end it attains an elevation of 520 feet A.T. and merges into a complexus of hillocks (elevation 560′) which in turn merge into a gravel plain ten feet higher. This plain decreases in height to the west and southwest.

Nearly a mile northeast of the northern end of the esker, there is another winding ridge, a little more than a quarter of a mile in extent. It is not so clearly defined as the one just described. In the intervening area, the gravel deposits are grouped into a confused assemblage of hillocks and hollows with no trace of an aggradation level, nor any semblance of continuous ridge.

Conditions of formation. There can be no doubt but that the esker-like ridges, the isolated kame hills, as well as the confused complexus of kame knolls, and the small terraces and plains are closely associated in origin. If it be assumed that these deposits were formed by sub-glacial streams, it follows that the bottom of the glacier across the valley was greatly honeycombed by numerous wide tunnels or low arches. The width of the kame area varies from a half a mile to a mile. Locally the gravel plains are fairly continuous over this entire distance. It seems impossible that the ice could have supported itself in so broad an arch, or series of arches as would be demanded by the conditions of this hypothesis.

On the other hand, it may be assumed that the deposits were not made until the main ice sheet had retreated from the immediate vicinity, although the valley was still somewhat clogged by blocks of stagnant melting ice, amid and between which the various knolls and plains were formed.

The direction of drainage is not altogether positively determined, although the weight of evidence seems to point to a northeastward direction. The gravel deposits are much lower near Portland than they are to the southwest, but, if the map is accurate, the highest level is not found at the southwestern end of the area, but in the vicinity of Johnsonville, whence they decline each way, more to the northeast than to the southwest. On the whole, however, judging from the slope of the deposits, the drainage was more towards the Delaware and the ice than away from it.

STRIÆ ON KITTATINNY (BLUE) MOUNTAIN

Along road from Water Gap village to Totts Gap.

Water Gap		S.10W.
¾ mile from Water Gap	Observations on neighboring ledges.	S.25W.
" " " " "		S.30W.
" " " " "		S.36W.
" " " " "		S.12W.
1¼ mile from Water Gap (local deflection due to topography)		S.5W.
Totts Gap. 200′ below summit on northern slope		S.35W.
1 mile north of Totts Gap	Observations near crest of second ridge, half mile apart.	S.35W.
" " " " "		S.35W.
" " " " "		S.30W.

Kittatinny Valley slate hills.

¾ mile west of Slateford .... S.50W.
1⅛ mile southwest of Slateford.................................. S.40W.
1 mile northwest of East Bangor, S.55W., S.45W., striæ not crossed.
Old Bangor Quarries—on west slope S.80W., at right angles to moraine.
Centerville, in front of Brick Church............................ S.25W.
One mile southeast of Centerville, at right angles to moraine, S.8W.

The striæ are almost too few to warrant any detailed inferences as to the direction of ice motion. The ice crossed Kittatinny Mountain obliquely, the average direction of the markings being about S.25-30W. On the lower hills to the north of this ridge the ice currents moved more nearly parallel to the trend of the ridges. The barrier interposed by the mountain deflected the basal currents slightly, but apparently had no effect upon those which crossed its crest. The meager observations made in Kittatinny valley indicate that the motion near the foot of the mountain was more nearly parallel to the trend of the ridge than toward the axis of the valley, where the direction accords more nearly with that over the crest of the mountain. The few observations made near the moraine indicate that the ice movement was in general at right angles to its course.

In addition to the excellent descriptions given by Dr. Kümmel, the writer may add a few of his own more limited observations.

Prof. Ward presents several bits of evidence in support of his view that all the glacial till found on the crest of Kittatinny (Blue) Mountain in Northampton and Monroe counties belongs to the Illinoian ice sheet rather than the Wisconsin according to other workers. One of the strongest points he makes is the greater age of the mountain till as compared with the till of the slate region. In his report he states that in the Illinoian "limestone fragments generally lacking in the till, for solution has removed them. The rare fragments found are large and are obviously loosened from the underlying bedrock. All of them show evidence of long weathering, being porous and even cavernous or fallen apart." (pp. 43-44.) This description is an excellent one for the Illinoian deposits known to the writer that are southwest of the Wisconsin terminal moraine. However, it does not fully accord with his observations of the till on the top of Kittatinny (Blue) Mountain, especially east of Tott Gap, at Fox Gap and west of Fox Gap to the Little Offset, where numerous blocks of fossiliferous Onondaga limestone, large and small, many of them remarkably fresh, no more

weathered than the Onondaga limestone boulders in the slate region, have been noted. They are associated with fossiliferous Oriskany sandstone boulders, rounded red Clinton sandstones, waterworn gray siliceous sandstones and black flint (Onondaga?).

On two different occasions known to the writer fossils were collected from large limestone blocks which were supposed to be in place, once on the crest of Kittatinny (Blue) Mountain and once in the Martinsburg region to the south. In each case the fossils were of Onondaga age and the blocks containing them had been brought from the north side of the mountain several miles distant.

These personal observations are offered as probable evidence that the Wisconsin ice sheet did pass over Kittatinny (Blue) Mountain as far west as the Little Offset as claimed by the earlier investigators. It seems fairly certain that the morainal deposits on the crest of the mountain are fairly thin and have not materially influenced the topography. No knob and kettle phenomena have been noted.

In 1881[13] Lesley wrote the following:

> At the Delaware Water Gap are terraces, kames, medial moraines and glacial striæ in abundance. But the great ice sheet passed diagonally over the top of the Blue (Kittatinny) Mountain without heeding the gap in the mountain.
>
> On the very crest of the mountain Mr. Lewis found a block of Helderberg (evidently Onondaga) limestone, more than six feet long, which had been torn from the ridge in the valley below, five miles distant.
>
> Other boulders of the same limestone, some of them more than thirty feet (30′) long have been carried over the top of the mountain and now lie on the upturned edges of the Hudson River (Martinsburg) slate formation south of it.

Prof. Ward's new interpretation, so briefly outlined here, has stimulated interest in the glacial problems of the region and is accordingly particularly welcome.

The terrace gravel deposits and outwash materials associated with the Wisconsin ice sheet were described briefly in the chapter on Physiography. In Bulletin G 10 of this Survey, Prof. Ward has presented much detailed information on this subject so that it does not seem advisable to discuss this subject here.

ILLINOIAN ICE SHEET

In a recent publication[14] of this Survey, Leverett has given (pp. 1-11) a comprehensive summary of the work done by previous investigators of the "extra-morainic drift" and has also described the Illinoian drift as it is developed in Northampton and Lehigh counties. He describes and maps the Illinoian terminal moraine in Saucon

[13] Lesley, J. P., Second Geol. Survey of Pa., Report C6, p. xiv.

[14] Leverett, Frank, Glacial Deposits Outside the Wisconsin Terminal Moraine in Pennsylvania: Pennsylvania Topog. and Geol. Survey Bull., G7, 1934.

Valley and that part of Bethlehem lying between the Lehigh River and South Mountain. The following excerpts from Leverett's report (pp. 63-72) deal with Northampton County.

Extracts from Leverett's report follow:

Character of the Drift

The Illinoian drift of this district consists mainly of a reddish clayey till. In places it carries sufficient gravel to warrant opening pits in it for commercial use. The clayey part of the till may have been derived largely from the residuary clay left from the solution of the limestone, but most of the stones in the till have come from other formations over which the ice sheet had passed before it invaded the limestone area. On the southern border of the limestone area the drift carries gneiss and other rocks derived from South Mountain.

Williams has given the following description of the till, and interpretation of its derivation.* The description appears to apply to a section near Bethlehem.

"It shows a surface clay, unstratified and carrying rolled stones from the Blue Ridge (Blue Mountain), and beyond (Oneida, Medina, Oriskany, Helderberg, Marcellus, Hamilton, etc.) and covering a till that varies widely in its nature, but is mainly of local stuff, of angular shape, mixed with a greater or less proportion of rolled material similar to that in the clay, and locally with angular masses of the same. This latter rests uniformly on glaciated rock in place. This section may vary by the omission of the till, or by the introduction of local stratified deposits of sand and clay.

Williams appears to have held the view that the residuary clay of the limestone was almost completely gathered up and reworked to form the till, for he found outcrops of the limestone within the glaciated district to be generally fresh rock. He also noted a general similarity of material from top to bottom, described as follows:*

"First, the admixture of fresh and oxidized materials at all levels, and the uniformity of oxidation at any point along a vertical section . . . This curious and persistent admixture proves that oxidation preceded glaciation. In the slate belt the proportion of decomposed slates increases from north to south, and the same is true of limestone in the limestone belt, only chert being found at the south.

In another paper† Williams interpreted the surface clay to be a deposit in ponded water, held in front of the receding ice border, to a level corresponding to the lowest pass on the Lehigh-Schuylkill divide, about 500 feet above sea level. He named the hypothetical body of water "Lake Packer" and called the surface clay "Packer clay." The question of the occurrence of such ponding is taken up on a later page.

Williams made the suggestion ‡ that drumlins may be present near Bingen, Siegfried, and Northampton, his statement being as follows:

"It has not been fully determined whether the ridges of unstratified gravel at Bingen, Siegfried, Northampton, etc., are drumlins or portions of lateral or terminal moraines. The two latter deposits are on the north bank of the Lehigh, and are ten to twenty feet thick, from half a mile long, and from a few hundred feet to a half mile wide. The chances are in favor of their being drumlins, and connected with the subglacial drainage of the region.

The present writer could find no drift hills in the vicinity of these places that have the form of drumlins. Furthermore, drumlins are not a product of subglacial drainage.

Several of the deepest exposures of drift in the Illinoian area south of Blue Mountain were examined by the writer and found to exhibit a wide difference in the character of material, as may be seen by the following notes.

A large clay pit at a brick plant one and a half miles west of Nazareth, about twenty-five feet in depth, exposes a brown till carrying only a small number of pebbles, a feature giving it superiority over more stony till for brick manufacture. The limestone pebbles have been leached from the till

* Williams, E. H., Jr., Am. Jour. Sci., 3rd ser., vol. 47, p. 34, 1894.
Idem. p. 35.
† Williams, E. H., Jr., Geol. Soc. America Bull., vol. 5, pp. 286-289, 1894.
‡ Idem. p. 289.

to a depth of fifteen feet, below which they are still present, and the matrix in this lower part is also unleached. This was the only pit examined west of the Delaware in which the depth of leaching is clearly shown. In most exposures the matrix is not sufficiently calcareous to give ready response to tests with acid. Limestone pebbles also are very scarce in some of the exposures so that thorough search is necessary to find one.

There is an extensive exposure of reddish-brown till along the railroad tracks at "Iron Hill," in the east part of Bethlehem, with a depth of thirty to forty feet. It is mainly a rather stony till, and includes rocks of various kinds, brought in from distant points to the northeast.

Was There a Lake Packer?

Williams has interpreted the upper or surface part of the Illinoian drift in the limestone lowland, and within the Lehigh drainage basin, to be a lake deposit, and he has given the name "Lake Packer" to the body of water which he thought occupied the lowland. He inferred that ponding occurred before the ice sheet had reached its culmination, and that it recurred as the ice border melted back across the lowland.* He based the presence of such a body of water in some degree on hypothetical grounds, and gave it the altitude of the lowest part of the divide between the Lehigh and Schuylkill drainage basins in the limestone lowland, about 500 feet above sea level. But he also cited places where clay deposits rest on undisturbed gravel, and drew the inference that the clay was not deposited by the ice sheet, for if it had been, the gravel beds under it would show disturbance. Any lake deposits made during the advance of the ice were covered by glacial material to the extent that the ponded area was invaded and occupied by the ice sheet. The deposits as now exposed are thus restricted by him mainly to material laid down during retreat of the ice border. This material termed "Packer clay" is described as follows in the paper above cited. From this description it will be seen that the "Packer clay" is of complex and varied character, much like till, and with little resemblance to the ordinary lake deposit.

"The clay is generally a reddish-brown, unstratified, sandy deposit, with a burden of glaciated, angular, and river-rolled material scattered irregularly through it. Very few striated stones have been found in the sections studied, and the bulk of the burden consists of river cobbles and pebbles, with a considerable proportion of perfectly angular fragments, derived from the rocks to the north of the locality where they occur in the clay. In the case of syenitic fragments, they occur near the South Mountain, where they could have been picked up by shore ice and carried a short distance. The greater proportion of the burden, however, are sandstones and chert, with a small amount of limestone and slate. The specimen of striated rock exhibited is from the clay, and shows the general freshness of the burden. The slates are generally fresh within, if oxidized externally, and workable slate can be found ten feet from the surface, whereas the average depth of decomposed soil over an unglaciated area, or one exposed to long atmospheric action, is from sixty to seventy-five feet.

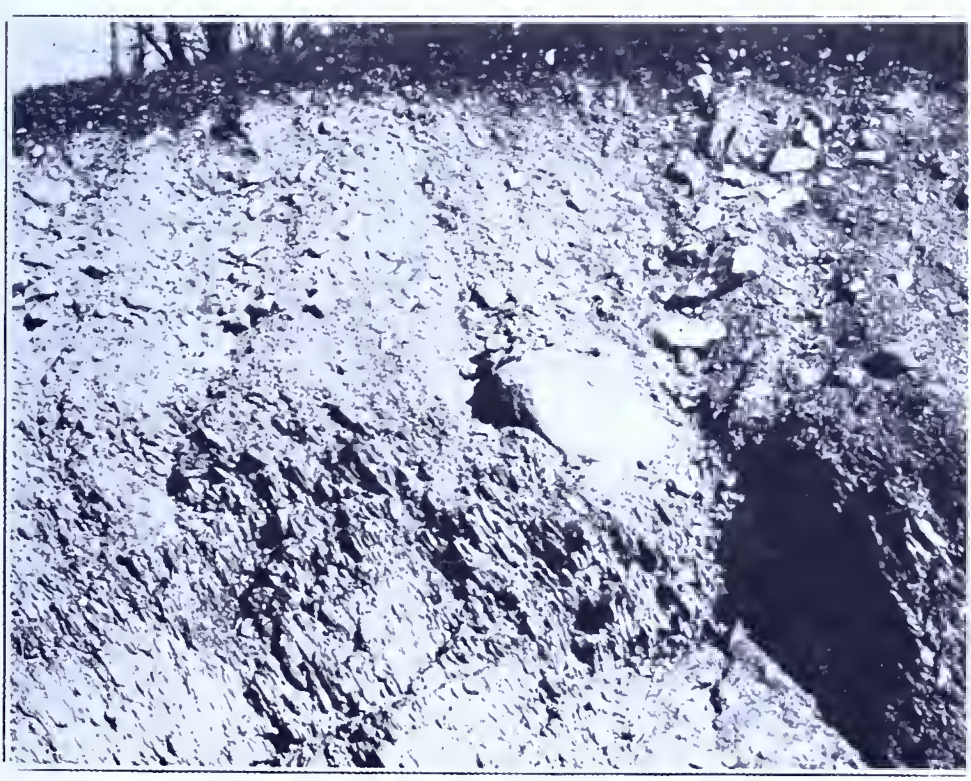
"The clay deposit varies from a perfectly clean clay to clayey sand as we go from the deep water of the south to the northern shallows. It is generally unstratified, but shows local areas of stratification. Its thickness varies from a few inches to twelve feet at West Bethlehem, but the general average is three feet.

"The "Packer clay" was thought by Williams to be absent from the part of Saucon Valley west and south of Hellertown. He interpreted this absence to denote that there was no outflow from the Saucon Valley past Leithsville to Durham Valley, and thence to Delaware River. He said that a flow over that divide would have distributed the clays over the Saucon Valley in great bulk. Concerning the state of oxidation of the clay (and this seems to include the till), Williams remarked:

"The high state of oxidation of the clay has been adduced as evidence of its great age, but the argument is worthless in view of the manner in which it was accumulated and the condition of the burden it carries. These glaciated, rolled and angular stones are generally fresh and unoxidized, as just described. We have, therefore, a highly oxidized clay throughout, bearing at all levels fresh material. The mixture is no older than the fresh part, and the oxidation of the clay is either preglacial, from its having been part of the soil of the region (as gneiss, limestone, and slate all rot to such a clay), or due to oxidation while it was being deposited. Judging from the state of certain portions of the till, the chances are in favor of the former supposition. These fresh fragments antedate the great moraine and show that it also is of recent date. It may be argued that the clay (Packer) is the ordinary boulder clay of subglacial origin.

* Williams, E. H., Jr., Geol. Soc. America Bull., vol. 5, pp. 286-289, 1894.

A. Discarded glacial boulders in brick clay pit of Illinoian till, Georgetown.



B. Drift on Martinsburg slate ¼ mile southeast of Lehigh Gap.

PLATE 17.

A. Illinoian till, Bingen.

B. Water-laid drift on Martinsburg slate, 1⅛ miles northeast of Walnutport.

If it were its deposition would have disturbed the stratification of the underlying gravels and sands, and there would not be the great proportion of angular fragments in the burden, nor, further, would we in hundreds of cases find the till shading gradually and conformably into the overlying clay.

Inasmuch as the presence and level of "Lake Packer" was made dependent on drainage over a pass in the limestone lowland outside the Illinoian ice border on the divide between the Lehigh and Schuylkill Rivers, and not on a slightly lower pass at Leithsville, between the Lehigh and the Delaware, the present writer gave considerable attention to the features at each pass. The lowest place on the Lehigh-Schuylkill divide is north of Topton at an altitude between 480 and 500 feet. * * * The pass at Leithsville, between Saucon Valley and Durham Valley, is at 445 to 450 feet, * * * or fully thirty feet lower than that near Topton. Williams suggested that the Leithsville pass had a higher altitude than that near Topton at the time the ice sheet was present and had later been cut down to its present level. He attributed the lowering to a concentration of drainage from bordering uplands, causing rapid cutting, whereas there was no such concentration of drainage from bordering uplands on the Lehigh-Schuylkill divide. The writer was unable to find evidence of a post-Illinoian lowering of the pass at Leithsville. At this pass the limestone floor has a thin deposit of cobbly clayey material indicating drainage across it of rather weak character. The pass is close to the Illinoian border and the deposit is probably an outwash from the ice sheet that occupied the Saucon Valley. The sluggish drainage is perhaps due to the partial blocking of the lower end of Durham Valley by the ice sheet in the Delaware Valley. It is probable also that water discharging across this pass was merely that coming from the small ice lobe that occupied the north end of the Saucon Valley. Its level may thus have had no relation to that of the drainage across the Lehigh-Schuylkill divide.

As to the disposal of water from the melting of the Illinoian ice lobe, two dissimilar modes of discharge have been considered. One is the escape of the water along the south edge of the ice sheet at the base of South Mountain between Bethlehem and the Delaware Valley. This may have been to a considerable degree submarginal rather than outside the ice edge, and similar escape may have been found along the Delaware from Easton to Riegelsville. The other mode of escape is by underground drainage through the limestone of the outlying district west of the moraine. Much of the present drainage goes through underground channels. Water from a moderate rate of melting of the ice may have been thus disposed of without causing ponding outside the ice border.

Some additional notes are offered to supplement Leverett's descriptions.

As one drives across the limestone valley of Northampton County he observes quantities of boulders collected from the fields and piled along the fences. In places these piles are very conspicuous but along the fences in other places there are very few. At one time the writer and his students attempted to differentiate between those places thickly covered with glacial debris and the sections where the glacial deposits are apparently practically absent. This plan was abandoned when it was found that careful search revealed their presence on all the uplands. On the slopes there is seldom any evidence of glacial material. In the slate area where the hillsides are steep and the divides narrow there are many areas where the deposits seem to have been completely removed by post-glacial erosion.

The thickest deposits, such as the one now being worked for clay by

the Zehnder Brick Co. in South Easton, the Nazareth Face Brick Co. near Georgetown, and the Saucon Valley Brick Co. near Bingen, seem to have accumulated in depressions in the preglacial surface. Descriptions of these deposits are given in the chapter on Economic Geology.

The size of the boulders varies greatly. In the Saucon Valley northwest of Hellertown there are numerous sub-angular Shawangunk and Devonian boulders six to eight feet in diameter. Boulders with typical Oriskany fossils, especially *Spirifer arenosus*, are fairly common. The larger boulders generally bear abundant glacial striæ and the cobbles and pebbles rarely do. The abundance of well-rounded stream-worn cobbles suggests that the ice sheet as it crossed the Delaware River valley must have picked up enormous quantities of alluvial material which it spread over Northampton County. Much black flint is present in the local Illinoian glacial deposits. This probably was derived from the Tomstown, Allentown and Beekmantown formations and was present in the surface limestone residual clay before the advent of the ice.

One of the interesting occurrences of the Illinoian is in the flat-bottomed valley at the head of the East Branch of Saucon Creek where the small settlement of Lower Saucon is located. It seems that the ice of Saucon Valley pushed eastward up the narrow portion of the valley to this more open part, carrying with it an abundance of cobbles of Silurian and Devonian age. One may wonder, however, whether these cobbles and pebbles have any connection with the high-lying gravels on the tops of the high hills south and east of Lower Saucon, dscribed under Jerseyan glaciation. Also boulders of gneiss are conspicuous in the glacial deposits of Saucon Valley.

The region east of Seidersville presents the best example of Illinoian morainal topography in the county. Hills and sags (knobs and kettles) are well exhibited here. A few wells have shown glacial deposits about 40 feet deep. Of course, there may be places where they are thicker. It must be recognized that these enclosed depressions may possibly be limestone sinks, since the water is not held in them but sinks quickly into underground limestone caverns.

Barrell and Williams believed that the ice of this period as it encountered the end of South Mountain south of Bethlehem pushed up to the crest of the mountain approximately 900 feet above sea level. Barrell (1893. See Bibliography) reports finding "a Medina or Clinton boulder about one foot diameter" almost at the crest of the mountain southeast of Lehigh University campus. Another explanation is that the boulder was brought here by the earlier ice invasion.

The writer has never found any of the glacial till of the region that contains sufficient calcareous matter to produce visible effervescence

with dilute acid. This test must not be applied in the vicinity of the cement mills without digging some distance below the surface, for there every exposed rock or bit of surface clay may have a film of pulverized cement rock on it. In places years ago when the mills threw much dust into the atmosphere even the bark of trees a few miles away would show this effervescence. No fresh limestone fragments have been observed. Instead all noted have had practically all the calcareous matter dissolved and the residual product readily crumbles into fine sand.

The entire subject of the Illinoian ice sheet in this region should receive more careful investigation by geologists familiar with glacial problems over a much larger region than Northampton County as there remain numerous unanswered problems.

PRE-ILLINOIAN (JERSEYAN) ICE SHEET

Glacial deposits extend beyond the Illinoian terminal moraine mapped by Leverett. Boulders and cobbles occur in the surface soils in many places. A deposit worked for brick clay near Shoemakersville, Berks County, appears to be glacial till. It therefore seems that a still earlier ice sheet crossed Northampton County but no deposits within the county can be definitely designated as belonging to such an ice sheet.

The only occurrences known to the writer that best lend themselves to this assignment are the gravels and cobbles that have been found on the tops of some of the gneiss hills in Saucon and Williams townships. They occur at elevations which Leverett regarded as higher than the Illinoian glacial deposits. On the other hand, they may be regarded as high-level alluvial deposits. All the materials are quartzite or sandstone and are well-rounded. A single quartzitic sandstone cobble about eight by four by two and one-half inches found at 600-feet elevation east of Steelys Hill, close to the Bucks County line, appears to be faceted and striated by ice action. Occasional sandstone cobbles, well rounded, are found on Steelys Hill at 600 feet, one mile east of Fairview School at 680 feet, west of Franklin School at 700 feet, and a half a mile west of Wassergass at 720 feet. The most extensive of these cobble deposits is south of Granite Hill at 740 feet above sea level. This corresponds to a similar deposit in Lehigh County a short distance southwest of Bethlehem. No doubt other occurrences exist but can scarcely be discovered except when newly-ploughed fields permit careful search in the surface soils.

The interpretation and correlation of these deposits await further investigation.

Alluvial Deposits

As discussed under Physiography, there are alluvial deposits along the major streams and some of the minor ones. These are mainly Recent although some probably antedate the glacial deposits. They are generally thin.

Colluvial Deposits

The colluvial or hillside talus deposits are well-developed along the lower slopes of Kittatinny (Blue) Mountain and the gneiss hills south of the Lehigh River and to a lesser extent on the minor hills. They are in process of accumulation and also destruction by weathering. Some of them may date back to the retreat of the glacial ice. In some of the deposits the blocks of stone are angular and of huge size. On South Mountain one can see many illustrations of exfoliation by which the blocks are changed into spherical boulders of gradually decreasing size.

Residual Deposits

The residual deposits of the region largely constitute the soils, which are discussed in another chapter.

STRUCTURE

By Benjamin L. Miller and Donald M. Fraser*

The structural features of the rocks of Northampton County are extremely varied and complex. Practically every type of geological structure is present. In places the structures have been determined with considerable certainty but in other sections they can only be inferred. The surficial cover of residual soils, talus and glacial debris conceals so large a portion of the strata that in places it is impossible to decide between different explanations that may be equally consistent with the known facts. New highway cuts, excavations and well drillings occasionally furnish desired information previously lacking. Present views are apt to be modified when and if new data in critical areas are obtained.

The present topographic features are the result of a combination of structural deformations and subsequent differential erosion. The hills are composed of rocks more resistant to erosion than the strata underlying the valleys, regardless of the original structures. The highest elevations in the county are produced by the resistant Silurian sandstones and conglomerates of Kittatinny (Blue) Mountain, almost the youngest rocks of the region, and the next highest hills are composed of the ancient pre-Cambrian metamorphic rocks.

Appalachian structure such as prevails throughout the entire Appalachian region is well exhibited in Northampton County. Following the deposition of thousands of feet of sediments in the great Appalachian Paleozoic geosyncline, compressive forces became active and the strata were thrown into more or less parallel longitudinal folds. The dominant force came from the southeast and the resulting folds have a northeast-southwest trend. Both the basement pre-Cambrian crystalline rocks and the overlying sedimentary strata participated in the folding. The older rocks were uplifted in the anticlines far above the down-warped younger rocks in the synclines.

Open symmetrical anticlines and synclines exist in some portions of the Appalachians, but in this region the compression was so intense that the folds are generally closed and show marked asymmetry. The beds of the northern limb of the anticlines, or the southern limb of the synclines, are usually considerably steeper than the corresponding beds of the other side. In the slate quarries where the workable slate beds are mainly preserved in synclines, the quarrymen designate the steep south side as the "crop" and the more gentle northern limb as the "run."

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* The pre-Cambrian structure section descriptions are by Fraser.

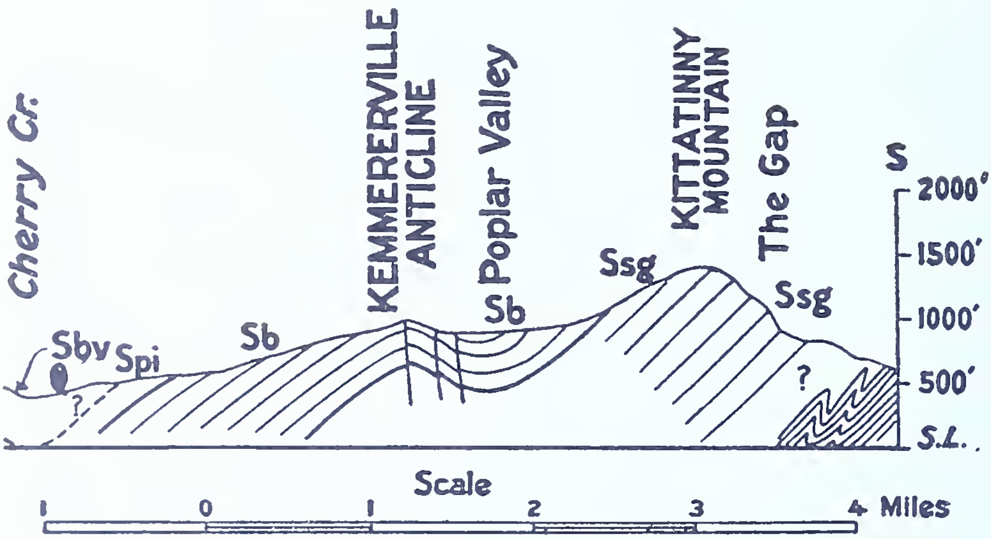

Figure 31. Geologic section across Kittatinny Mountain near Delaware Water Gap.

So great was the compression in certain sections that the folds have been overturned, as will be presented in the descriptions of local structural features.

Few unmodified anticlines and synclines are present in the county, especially in the southern section where the folds involved older more massive and, consequently, stronger crystalline rocks as well as the less resistant overlying sedimentary strata. In scores of places the folds are broken by faults. These range in magnitude from microscopic size to displacements of several thousand feet. The maximum fault displacement that has been determined is along the north side of Saucon Valley just west of the Northampton-Lehigh county line where Jacksonburg limestone has been dropped 600 feet below the adjacent hill of gneiss, a total displacement of approximately 4,000 feet and probably considerably more.

The type of faulting in the region has long been discussed. Where there is evidence of faulting, some workers have interpreted the present distribution of the strata as due to reverse high-angle faults or low-angle overthrusts; others favor high-angle normal faults. Seldom are the fault contacts visible and the existing data do not permit a positive decision. In many places any one of these views might explain the observed facts.

The major faults, whether normal or reverse, tend to follow the general northeast-southwest trend of the strata. Where the present ridges consist of pre-Cambrian crystalline rocks, faults are common along the lower slopes of one or both sides. The actual faults are

usually concealed by talus. The presence of these faults is determined by formations younger than the Hardyston in contact with the pre-Cambrian rocks or by discordant dips or strikes. Many of these faults are marked by springs or seepages.

The general structural pattern of the region, where the crystalline rocks and Paleozoic sedimentaries are both present, consists of ridges of pre-Cambrian rocks separated by generally narrow steep-sided valleys, although there are a few fairly wide flat-bottomed valleys. These valleys are normally floored by Paleozoic strata which have been down-folded or down-faulted or both.

Where only sedimentary rocks are present, such as prevail north of the Lehigh River, with the exception of Chestnut Ridge and Pine Top-Camels Hump, faults are indicated by lack of alignment of the outcropping formations. The structure, however, is of the same essential type.

The heterogeneous character of the rocks of the region and their consequent varying strengths have resulted in numerous modifications of the structural pattern. Even if the compressive force from the southeast were everywhere uniform, which is an improbable assumption, the resolution of forces due to unequal resistances of the rocks would cause buckling and breaking of the rocks along other directions than the major ones. This is seen in several places where folds and faults of varying trends are present. In places close folding, crumpling and faulting are so complex that it is difficult to explain the sequence of events even in good exposures, and impossible where outcrops are infrequent. Although dip and strike have been determined at practically every outcrop of the sedimentary strata, these have not been placed on the map as they are apt to confuse rather than to clarify. If the surface cover could be removed, it is probable that axes of folds and directions of faults placed on the map would produce an almost inextricable tangle. A much larger scale than that of the present map would be necessary in order to represent them.

Whenever any company proposes to make any considerable use of any of the rocks of the county it usually becomes necessary to make a detailed investigation of the structure by surface trenching or by drilling. The information available from surface outcrops is generally too meagre in a region with such complicated structure.

It might seem that the greatest complexities would be in the weaker Paleozoic strata adjacent to the stronger metamorphic rocks of the pre-Cambrian. This is not always the case, as is shown in the illustration (pl. 18) of the intricately folded Beekmantown limestones at Northampton.

The periods of folding and faulting in the district that occurred

during the Paleozoic and Mesozoic eras are fairly definitely known. Those of the pre-Cambrian are only vaguely understood. Igneous activities, such as the up-welling of molten matter, were probably active agents in the production of some of the structural features of the pre-Cambrian.

Three known periods of deformation occurred since the opening of the Paleozoic and probably several during the pre-Cambrian. These are the Taconic Disturbance at the close of the Ordovician, the Appalachian Revolution that closed the Paleozoic era, and the normal faulting of the Triassic and post-Triassic. How effective the last of these was in this region is not definitely known. Faults are common in the great thickness of Triassic sediments that lie south of the county and it is believed that some of the faults outside the Triassic basins of sedimentation were similarly produced in Triassic or post-Triassic time.

Before discussing individual areas it seems well to refer briefly to an interpretation of South Mountain structure recently offered by Stose and Jonas[15] and discussed by Miller and Fraser[16]. According to this hypothesis most of the pre-Cambrian hills of the Reading region are part of a great overthrust block described as follows:

> Most of the mountain area from its end southwest of Wernersville to South Mountain south of Emaus, a distance of over fifty miles, and probably its extension across Pennsylvania to Easton, is believed by the writers to be a part of a great overthrust sheet which has ridden northwestward on a flat fault plane in the crystalline core of the mountains over lower Palezoic rocks. (p. 763.)

The authors of this volume believe that all positive data on the subject as well as evidence of a probable character are opposed to the acceptance of such an interpretation for any portion of Northampton and Lehigh counties as well as the area of Berks County northeast of Reading. According to Stose and Jonas the pre-Cambrian rocks of the region rest on Paleozoic rocks whereas all evidence in possession of the writers leads to the belief in the indefinite downward extension of the crystalline rocks.

Although there are several recognized unconformities in the Paleozoic series of rocks, as shown in the columnar section, these do not seem to have greatly affected the present distribution of the different formations. The greatest occur at the contact of the Hardyston and the pre-Cambrian and at the base of the Brunswick. The latter is not of much importance in the present study owing to the small area of the Brunswick. Elsewhere in this volume the unconformities be-

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[15] Stose, George W., and Jonas, Anna I., Highlands Near Reading, Pennsylvania; An Erosion Remnant of a Great Overthrust Sheet: Geol. Soc. Am. Bull., vol. 46, pp. 757-780, 1936.

[16] Miller, B. L., and Fraser, D. M., Geol. Soc. Am. Bull., vol. 46, pp. 2031-2038, 1936.

tween the Jacksonburg and the Beekmantown, the Jacksonburg and the Martinsburg, and the Martinsburg and Shawangunk have been discussed.

A few local studies of joints have been made, mainly in the slate region where they are of economic significance. In general, joints are abundant and trend in many directions, as would be expected in a region so intricately folded and faulted. This condition partly explains the few quarries operated for dimension stone.

Local Structural Features

CHESTNUT HILL AREA

The formations in Chestnut Hill may be divided into three groups: the serpentine belt, the Moravian Heights formation, and the pre-Cambrian igneous rock belt, which includes Pochuck more or less assimilated by the Byram, the Byram, and intrusive pegmatites. These divisions in the order named occupy northeast-southwest strips from the southern to the northern edge of Chestnut Hill. The serpentinized limestone occupies a good portion of the south slope of the ridge, and the igneous rocks make up the north slope and the crest of the ridge, with the Moravian Heights formation as a thin zone between the other two groups.

The structure of Chestnut Hill is dominated by two sets of faults. The more extensive set extends northeast and southwest. The second set, consisting of cross faults which have displaced the first set, extends more to the north and south than otherwise. In this second set, the fault cutting the ridge at Bushkill Creek and the one lying three-quarters of a mile to the southwest, have a general north-northeast trend. Two smaller cross faults approximately one-half and three-quarters of a mile respectively east of Bushkill Creek have a north-south trend.

Although the fault bordering the northern edge of the ridge has commonly been thought to be a thrust fault, this interpretation might well be questioned. Along the eastern side of Bushkill Creek the Paleozoic limestone lying northwest of the fault is only a few feet northwest of an outcrop of the pre-Cambrian rocks. Furthermore, the limestone extends up the slope to the northeast in such a position that any fault plane separating the two formations must necessarily be of a high-angle type. In this particular exposure it would seem as reasonable to propose a vertical fault or a normal fault dipping to the northwest as to suggest a high-angle thrust or reverse fault dipping to the southeast. Furthermore, the relations of the limestone beds to the pre-Cambrian rocks southwest of Bushkill Creek do not encourage the belief in a low-angle thrust. The fault south of the

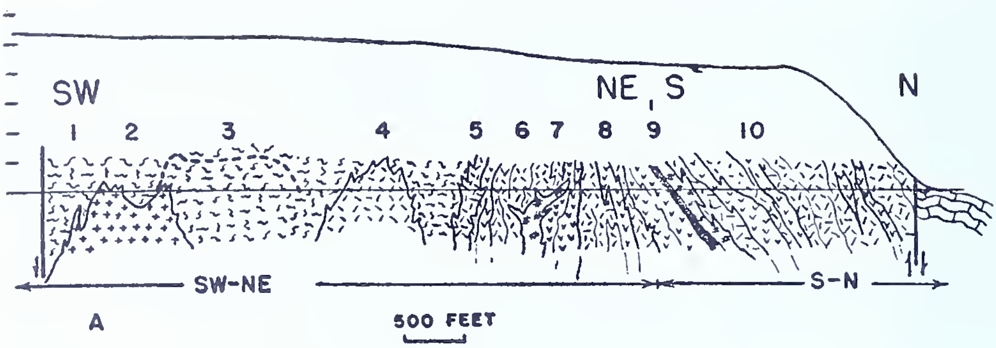

Figure 32. Geologic section of Chestnut Hill showing the pre-Cambrian formations and members exposed along River Road from a point southwest of Williams quarry to the north end of Weygadt. Tomstown limestone is in fault contact with the pre-Cambrian along both sides of the ridge.

1. Serpentine. 2. Pink pegmatite invading serpentine. 3. Heavy dashed line indicates Williams quarry. 4. White pegmatite invading serpentine. 5. White and pink pegmatitic Byram with streaks of epidotized feldspar. 6. Whitish and pinkish Byram. 7. Tourmaline-bearing pegmatite. 8. Pochuck gneiss with introduced Byram granitic material. 9. Moravian Heights invaded by Byram. 10. Heterogeneous mixture of Byram containing Pochuck in various stages of assimilation, the whole mass being transgressed and in places intimately penetrated by tourmaline pegmatites.

Chestnut Hill ridge is thought to be a normal fault along which the Paleozoic limestones were dropped below the level of the older crystalline rocks lying to the north. It may be a vertical fault as no exposures were found where its true nature may be determined.

An interesting structural feature exists in the area north of the southwestward extension of Chestnut Hill and roughly three-quarters mile southeast of Coilton. In this district a narrow strip of the serpentinized pre-Cambrian limestone has a northeast-southwest trend and is in contact with Paleozoic limestone on both the northern and southern sides. The existence of this strip of pre-Cambrian serpentinized limestone surrounded by Paleozoic limestones is explained only if we assume that it is completely bounded by faults and that it has been brought into its present position by movement along these planes. This narrow belt of serpentine had been thought to end against a northwest-southeast fault along Bushkill Creek until C. K. Cabeen recently showed, in an unpublished manuscript, that it extends across the creek to the southwest. The structures of the Chestnut Hill serpentine rocks have been described by Cabeen as follows:

Folding of great intensity, in addition to other metamorphism, has prevailed to such an extent that bedding has disappeared and an exact determination of the structure is not possible. Certain general relations may be stated.

The trend of the serpentine outcrop, and of all the rocks of the region, is N. 45° E. This is also the trend of the foliation in the talc and serpentine and probably the bedding also. The Williams quarry offers the best place for measurements. In the west end of the quarry the dip of the foliation is SE. 30°. The center of the quarry and north end is so badly crumpled that no general dip can be measured; some slickensided surfaces are vertical. Part of an overturned fold is shown. . . .

There are many fractures, some branching, but most of them conform to the folding and shearing or at 45° to them. Many of the fractures are filled with calcite, often fibrous, which is considered pseudomorphous after asbestos, which is not always completely replaced. The fibrous calcite is often parallel to the walls and slickensided, sometimes at an angle to walls, less often perpendicular to the walls, all indicating movement in the mass. Chrysotile may occur perpendicular to the serpentine walls, but without a dividing center line of chromite as reported for asbestos in basic igneous rocks.

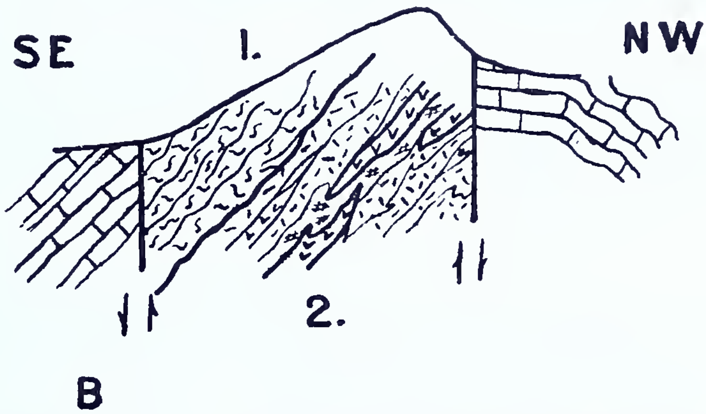

Figure 33. Geologic section of Chestnut Hill showing the pre-Cambrian formations exposed along the highway following Bushkill Creek from the south to the north side of Chestnut Hill. Tomstown limestone is faulted against the pre-Cambrian at both ends of the section.
1. Serpentine. 2. Byram granite gneiss with assimilated Pochuck.

CAMELS HUMP-PINE TOP RIDGE

A belt of pre-Cambrian rocks forms the Camels Hump and Pine Top hills and extends across Monocacy Creek southwestward to a point just beyond the Northampton County line. The elevation of this belt decreases from the peaks at the eastern end to the very low topographic expression to the southwest. Although there are no exposures of the actual contacts of the pre-Cambrian with the overlying rocks, the interpretation of the structure of this region is as follows:

Except for the occurrence of Hardyston dipping south from the south side of Camels Hump and possibly small remnants of Hardyston toward the southwestern end of the area, the pre-Cambrian rocks are in fault contact with the Paleozoic limestones. Both the northwestern and southeastern sides of the ridge from Pine Top southwestward are interpreted as fault contacts. The northern side of this ridge is thought to have been determined by the southwestward exten-

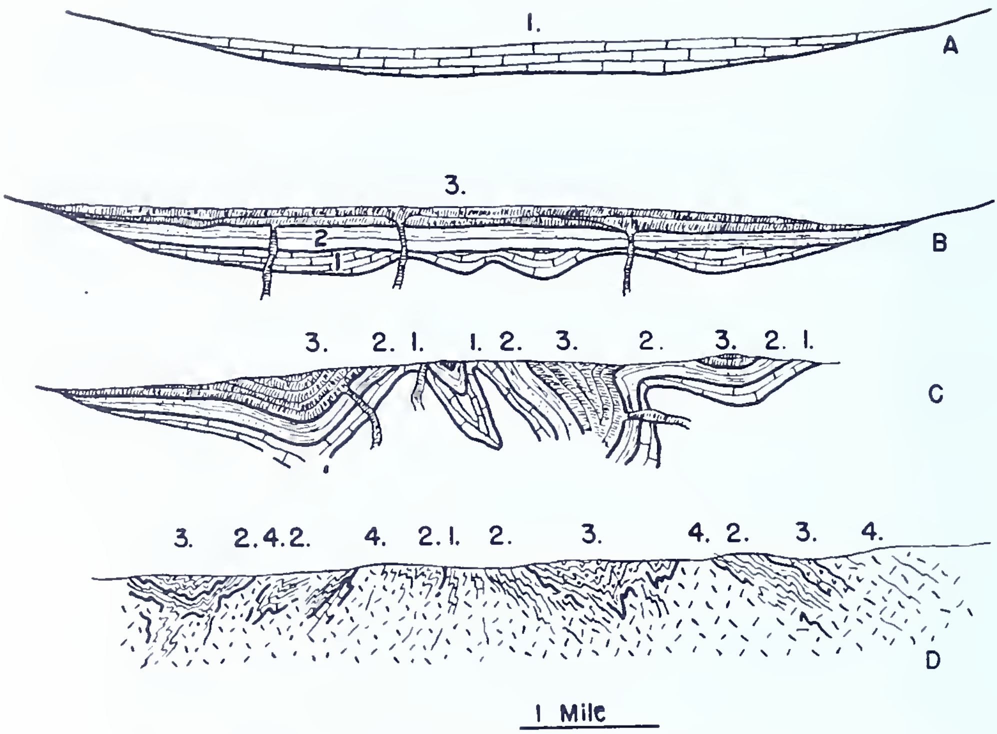

Figure 34. Series of diagrams showing an hypothetical sequence of events resulting in the present relationships between the pre-Cambrian rocks of Northampton County.

A. Deposition of the Franklin limestone.

B. Folding and erosion of the Franklin with the subsequent deposition of the Moravian Heights shaly sandstone and the accumulation of lava flows which will later be metamorphosed to the Pochuck.

C. Folding and partial erosion of the complete series. During and following this period of deformation the rocks were dynamically metamorphosed.

D. Metamorphosed rocks derived from the old sediments and lavas intimately invaded by a granite magma with partial assimilation and widespread introduction of granite liquids.

1. Franklin limestone.
2. Moravian Heights (shaly sandstone).
3. Pochuck gneiss (lavas).
4. Byram granite.

sion of the same fault that delineates the northern edge of Chestnut Hill north of Easton. The sag pond at Green Pond is thought to be a topographic expression of the line of the fault where it traverses limestone beds between Chestnut Hill and Camels Hump, the upthrow not being sufficient to bring the pre-Cambrian above the present surface. Just as in the Chestnut Hill area, this fault in the Camels Hump-Pine Top district has been long considered to be of the thrust type. Such an interpretation, however, may well be questioned and the fault may be either vertical or of normal character dipping to the north. The fault on the southern side of the ridge from Pine Top to

the southwest is thought to be a normal fault with the limestone area to the south dropped in relation to the pre-Cambrian belt. This fault, too, may be vertical and the pre-Cambrian ridge be dominantly a narrow horst block. The displacement on the northwest side where gneiss is in contact with Beekmantown limestone is much greater than on the southeast side where the gneiss is in contact with the Tomstown.

The more normal east trend of the Camels Hump end of the ridge in variance with the northeast trend of the remainder of the ridge to the southwest, together with the presence of a valley between the two parts, suggests the presence of a cross fault having a north trend at this point. That a structural break does exist along this general line is further indicated by the experience of the National Cement Company whose quarry is about a mile to the northeast. It was found that in pumping the water from the quarry the springs between their quarry and Camels Hump were affected much more than the springs to the southwest.

RIDGE ONE MILE NORTH OF HELLERTOWN

A small ridge extending from the roundhouse of the Reading Railroad near Hellertown eastward about one and one-quarter miles to a point where it is separated from the higher pre-Cambrian hills by a narrow valley is of special importance. A cut behind and on both sides of the roundhouse shows good evidence of repeated thrust faulting. At this place the ridge exhibits imbricate structure. The pre-Cambrian crystallines and the Cambrian limestone are the formations involved in the repeated faulting. The limestone disappears to the eastward and Hardyston comes in toward the eastern end of the ridge.

MORGAN HILL SHEAR ZONE

This small area is one of considerable interest not only because of the faults but also because of the interesting relations between the supposed Hardyston sediments near the eastern end and the alkalic-silicic type of invasion of those sediments. This latter feature is discussed under the topic of igneous activity of Paleozoic age.

The most highly developed zone of shearing found in the pre-Cambrian rocks of Northampton County is exposed along the steep southeastern slope of Morgan Hill. The rocks involved are Byram gneiss and pegmatitic members of this formation. A short distance to the southwest the Moravian Heights formations, greatly invaded by the Byram, is also broken by this shear zone. The total thickness of material involved is on the order of a quarter of a mile. Within this belt the crystalline rocks have in many places been reduced to mylonite and everywhere show evidence of granulation and stretching as a re-

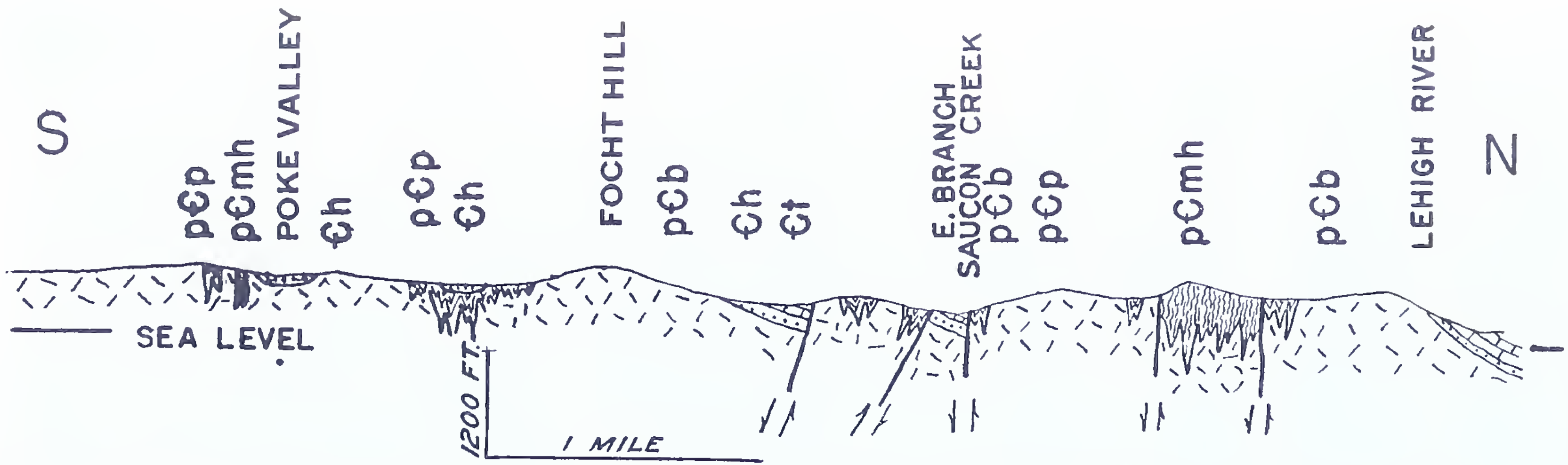

Figure 35. Geologic section of the pre-Cambrian rocks and the infolded and infaulted Paleozoic rocks from the Northampton-Bucks county line northward to the Lehigh River one and one-half miles southeast of Middletown.
pCmh—Moravian Heights formation; pCp—Pochuck gneiss; pCb—Byram granite gneiss, all pre-Cambrian and Ch, Hardyston quartzite and sandstone; Ct, Tomstown dolomite, both Cambrian in age.

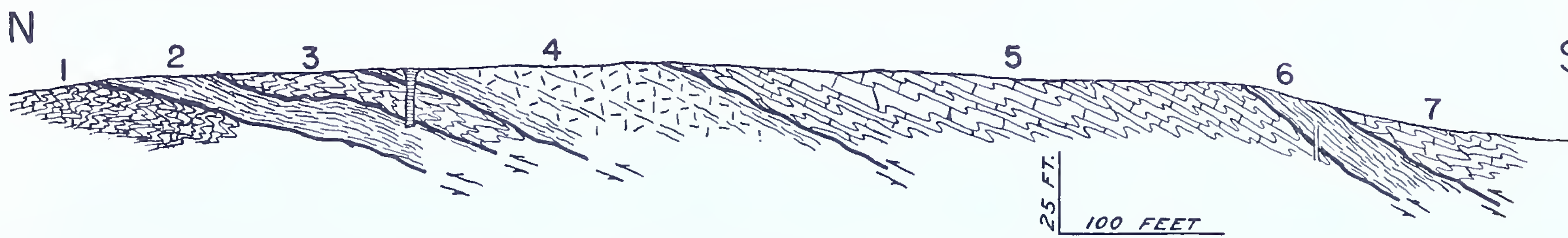

Figure 36. Section exposed in the western end of the low ridge one mile north of Hellertown.
1. Sheared Tomstown limestone; 2. Highly sheared Byram granite gneiss; 3. Sheared Tomstown limestone; 4. Byram, sheared near the fault contacts with Tomstown above and below but more massive near middle; 5. Tomstown limestone; sheared more highly near the faults; 6. Highly sheared Byram; 7. Tomstown limestone inferred due to its presence farther to the south. The feature between 3 and 4 is a concrete drainage channel. The above section is exposed in a cut behind the Reading Railroad round house north of Hellertown about one mile.

sult of differential movement along planes that dip southward at an angle close to seventy degrees. Although the broadest extent of the sheared area is along the ridge near the Delaware River, evidence of the intense differential movement within the rocks continues at least as far to the west as Fairview School. In the road cut south of the school is an exposure of a vitreous quartz formation which appears to be an irregular veinlike mass occurring in crushed Byram gneiss. Under the microscope the quartz is seen to be intensely granulated and is a typical mylonite. This material is as highly mylonitized as any material found in the county.

The shear zone and the occurrence of mylonitic material on top of the pre-Cambrian ridge are of interest in connection with the suggested overthrust origin of the pre-Cambrian belt. If such a theory of origin is correct, one would expect maximum shearing and granulation along the major thrust plane. Although sheared and crushed rocks are found in many places where they might be interpreted as occurring along such a thrust, the occurrence of the most highly developed shear zone completely within the pre-Cambrian rocks (rather than at the contact of pre-Cambrian with Paleozoic rocks) and the finding of mylonitic material on the crest of the ridge are evidence in opposition to a major thrust underlying the pre-Cambrian rocks.

SECTION BETWEEN SOUTH MOUNTAIN AND KITTATINNY (BLUE) MOUNTAIN

As shown on the geologic map, the formations between South and Kittatinny Mountains crop out in narrow to broad bands trending east to northeast. Northward from South Mountain the sequence of rocks is regular from the pre-Cambrian to the Silurian. Each formation in turn passes from view by dipping northward beneath the next younger series of strata. There are several local exceptions to this condition, the most prominent one being the ancient crystalline rocks of Chestnut Ridge and Pine Top-Camels Hump, already described.

This general regular succession might imply simple structure, which is not the case. The geologists of both the First and Second Geological Surveys of the State clearly appreciated the complex structural features of the Lehigh Valley. J. P. Lesley* in 1875 aptly characterized the situation in the following paragraph describing the structures of the Cambro-Ordovician limestones.

> It seems a very easy matter to obtain the knowledge which we want in so open, well-formed, almost level valley, bounded on one side by a mountain faced by a well-known rock *underlying* the limestones, (Potsdam s. s., No. I [now known as the Hardyston],) and in the other by hill slopes of unmistakable *overlying* slates, (Hudson River, No. III [Martinsburg]). But what seems a facility turns out to be the principal difficulty. What seems so smooth and regular a surface conceals one of the most contorted, twisted,

* Lesley, J. P., Report D, pp. 59-60, 1875.

fractured, cleft, plicated, complicated and even overturned set of subsoil rocks in the world. Besides the three or four large and pretty regular anticlinal waves which issue from the South Mountain and the hills of Easton and strike diagonally westward up the valley toward Port Clinton on the Schuylkill, there are hundreds of sharp little rolls which seem to defy classification, and most of these are almost entirely concealed by a top covering of mouldered limestone clay, soil and vegetation.

Starting at South Mountain one should find the Hardyston everywhere cropping out near the base of the steeper slope. This is the case on the north side of Morgan Hill and in a few other places farther west. Elsewhere a downward movement seems to have faulted out the Hardyston at the present surface. In southwest Easton a small block of Jacksonburg and Beekmantown has been down-faulted into the Allentown.

Along the Central of New Jersey R. R. about one-fourth mile east of the mouth of Nancy Run there is a series of minor faults and one large fault in which a great block of Allentown limestone has been overturned, as beautifully shown by the upsidedown position of the heads of *Cryptozoa*. An overturned fold with movement from the southeast has passed into a thrust fault. Plate 20, A.

A similar overturning of *Cryptozoa*-bearing dolomitic limestone, less well exposed, can be seen along the east side of Monocacy Creek about midway between Bethlehem and Pine Top.

Along the Central Railroad of New Jersey in southwest Freemansburg a high wall of Tomstown limestone is most intricately folded and faulted.

The finest example of minor folding in the county and perhaps in the State is well shown in the north wall of an abandoned limestone quarry along Dry Run in the south part of Northampton. (Plate 18.) The beds are Beekmantown limestones. When one finds folds of this sort exposed he can appreciate the unsatisfactory and erroneous conclusions that might be reached on the basis of occasional dips and strikes of sparse outcrops.

West of Brodhead at the National Cement Co. plant a downward folded and faulted block of Jacksonburg is underlain and surrounded by Beekmantown limestone. A small area of Martinsburg about half a mile southwest of Green Pond is similarly explained.

The Jacksonburg thin-bedded argillaceous limestones were crumpled rather than folded. There are some fairly regular folds and faults but generally the rock yielded by minor folds and by slipping of bed on bed. Slickensides coated with graphitic carbon are abundant in some quarries and also numerous calcite and quartz veins formed in the cavities resulting from the crumpling. Flowage and slatey cleavage make determination of the bedding planes difficult in places.

PLATE 18.

A. Folded Beekmantown limestone, south part of Northampton.

B. Front view of folds.

PLATE 19.

A. Folded Jacksonburg cement rock, Northampton.

B. Anticline in Allentown limestone, right bank of Monocacy Creek, Bethlehem.

Thrust faulting also occurs. A good example of this is a mass of Beekmantown dolomitic limestone exposed on top of Jacksonburg cement rock in the south part of the large quarry of the Lehigh Cement Co. at Sandts Eddy.

In the Beekmantown formation where dolomitic and low-magnesian strata are interbedded, a peculiar type of structure is developed. The relatively more competent dolomitic beds have been intricately folded and show the character of the folding whereas the weaker low-magnesian beds were made sufficiently plastic by compression to deform by flowage, and old bedding planes are almost obliterated.

The Martinsburg slates have been greatly folded and in some places faulted. Fine examples of overturned folds can be seen in some slate quarries. The most important structural feature of these rocks, however, is the slatey cleavage. In some places it is not well developed but in others even the thin, interbedded, calcareous sandstones exhibit cleavage planes.

Both in the slates and the limestones it is common to find marked thickening of the beds at the anticlinal and synclinal axes and resultant thinning along the sides. Many fine examples of this kind can be seen in the slate quarries.

The south dip of the Shawangunk conglomerate on the southern slope of Kittatinny (Blue) Mountain along the new highway that passes through Little Gap is not understood. It has been generally believed that the basal beds of the Shawangunk dip to the northwest all along the mountains as they do at the Lehigh Gap and Delaware Water Gap and that there is no fault between them and the Martinsburg. The Little Gap occurrence suggests a fault. The deep talus along the slopes of the mountain conceals the strata so generally that it may not be possible to determine the true structure here. If and when the mountain is tunneled, as proposed in order to bring water from north of the mountain to Bethlehem, this will be an interesting section for study.

SAUCON VALLEY SECTION

The geological structure of Saucon Valley is complicated and is only partly understood. The major structure has been explained by some as a syncline and by others as a graben. It is probable that a combination of downward folding and faulting is responsible. The fairly regular occurrence of the Hardyston along the slopes of the gneiss hills in the eastern and southern boundaries of the valley with the Tomstown limestone adjoining suggests synclinal folding, whereas the almost complete absence of the Hardyston along the north sides gives evidence of faulting. The vertical displacement of 4,000 feet

along the south side of South Mountain a few miles southeast of Seidersville in Lehigh County, previously mentioned, is sufficiently great to account for the valley. With these facts it seems best to explain the structure as a syncline which has been profoundly faulted along the northern side of the valley.

The gap in South Mountain through which Saucon Creek leaves the valley and enters the Lehigh River is floored with limestones. The presence of Hardyston in its normal position overlying crystalline rocks at the eastern nose of the mountain at Northampton Heights suggests downward folding, whereas its absence at the western nose of the mountain south of Freemansburg indicates downward faulting. A recent boring just south of the gap along the Bethlehem-Hellertown road passed through Tomstown limestone to a depth of 659 feet without encountering the Hardyston. This break in South Mountain therefore appears to be due partly to a synclinal fold and partly to downward faulting.

The fairly flat-bottomed irregularly-shaped valley in which the hamlet of Lower Saucon is situated has long been a structural problem. The hardness of the water in some of the wells indicates that part of the valley is underlain by limestone, presumably Tomstown. The presence of the Hardyston on the lower slopes of the gneiss hills in places suggests a synclinal fold but its absence in other places must be explained by faulting. At no place are the sedimentary rocks found in place, so no dips and strikes are obtainable. It therefore appears that the valley is the result of a downward fold that has been complicated by several normal faults of different trend.

The minor structures in the Saucon Valley are varied and complex. One of these near the Lehigh Valley R. R. roundhouse, involving crystalline rocks and Tomstown limestone in a series of small thrusts, has been described on an earlier page.

PORTLAND SECTION

The area of Allentown, Beekmantown and Jacksonburg limestones in the vicinity of Portland is of considerable structural interest. It forms a wedge block bounded by faults on both sides. The fault on the north side bringing the Martinsburg in contact with the Allentown represents a greater displacement than the one on the south side that, near the river, cuts out only the upper part of the Jacksonburg, but becomes progressively greater to the west, where it likewise brings the Allentown and Martinsburg in contact.

PLATE 20.

A. Faulted and overturned Allentown limestone, bank of Lehigh River, half a mile east of Freemansburg.

B. Slaty cleavage in argillaceous sandstones, upper member of Martinsburg formation, Lehigh Gap.

PLATE 21.

A. Faulted gneiss in cliff at Weygadt, north of Easton. Broad face shows slickensided surface.

B. Rock fall on Delaware River road at Weygadt caused by faults.

ECONOMIC GEOLOGY

By Benjamin L. Miller

In 1925, this Survey published a report on the Mineral Resources of the Allentown Quadrangle[17] in which the economic mineral products in that quadrangle were described. This quadrangle embraces a large part of Northampton County so that a report on the economic geology of the county necessitates considerable repetition. Such a procedure, however, seems desirable inasmuch as this atlas is now out of print and copies are not obtainable. Portions are taken literally from this atlas with little or no change, and without using quotation marks and references.

Northampton County contains deposits of both the metallic and non-metallic economic minerals. Iron ore is the only one of the metallic variety that has ever been of any consequence, although some prospecting has been done for both copper and manganese. The non-metallic products, on the other hand, are varied and constitute an extremely valuable asset. The cement rocks, limestone and slate have been utilized to such an extent as to make this district outstanding in the mineral industries of the State.

Iron Ores

Although the iron ores of Northampton County are not being worked at the present time, they have been of the greatest importance in the economic development of the region. For nearly 100 years the mining of iron was an extensive industry in this section and only within the last few years has it ceased entirely. The manufacture of iron and steel, which began when the iron mines were in active operation, still continues to be one of the principal industries of the region, even though all the ore used now comes frcm Michigan, Minnesota, Wisconsin, New York, New Jersey, Cuba, Chile, Sweden, Greece, and other places. The closing of the mines is due to several causes, among which the most important is the improvement of transportation facilities, which permits higher-grade ores from other regions, that can be procured in great quantities at low cost, to compete with the local ores. The imported ore is also of more uniform grade and can be obtained regularly in any quantity desired. Though the ore in some mines was practically exhausted, this condition does not apply to the greater number of the deposits.

[17] Miller, B. L., Atlas of Pennsylvania, No. 206, Allentown Quadrangle, Mineral Resources: Pennsylvania Topog. and Geol. Survey, 195 pp., 1925.

The history of the earliest development of the iron industry in eastern Pennsylvania is somewhat obscure. All records seem to indicate that the first iron ores used were the magnetite ores of Durham, Bucks County, about two miles south of the Northampton County line. These deposits seem to have been guarded by the Indians as early as 1698, which probably means that the early Dutch and Swedish traders had recognized their value. A tract of 5,000 acres containing the Durham iron deposits was part of William Penn's purchase from the Indians and was surveyed by Jacob Taylor in 1701. There was a settlement on this tract as early as 1723, and it may be inferred that the deposits were operated at that date, although the first definite information obtainable is that a furnace was erected at Durham in 1727 and put in blast in the spring of 1728. With iron furnaces in operation so near the borders of Northampton County, it is probable that some magnetite may have been mined in the nearby hills of this county where ore of the same kind occurs in small quantities.

A bloomery is said to have been built near Jacobsburg, a few miles north of Nazareth, in 1805 and another one in 1809. Both of them used local limonite ores, probably from mines in the vicinity of Nazareth. In 1824-25, Mather S. Henry erected a blast furnace north of Nazareth, which was put into operation in May 1825. He states that "the principal part of the ore used was the columnar or pipe species of hematite ore of Lower Mount Bethel Township, as also the brown hematite from Williams and Hanover townships in Northampton, and Whitehall in Lehigh counties.[1]" This is the first definite information regarding the use of the iron ores of the county.

Between 1830 and 1840 many limonite ore mines were worked along the south side of Lehigh River between Easton and Bethlehem. The condition of the industry in the summer of 1840 is thus described:[18]

> About three miles westward from South Easton, a mine has been opened, at Jacob Woodring's, in a hollow between two spurs of the primary chain. It was not wrought at the time of our examination. The shaft here is said to be 90 feet deep, passing through diluvium and clay for 55 feet, before any ore was found. The ore is moderately rich, but contains some manganese. The limestone shows itself on the surface, about 300 yards north of the ore. Westward of these localities, surface signs of ore are abundant, as at Ihrie's and Brotzman's, half a mile south of the Lehigh. At Brotzman's, where some manganese is associated with the ore, the diggings were made probably too high in the side of the hill, being apparently outside of the edge of the limestone. The ore here is rough and sandy, and contains compact black oxide of manganese in some abundance. A little hill, further west, on the same farm, lying within the limestone, shows a much better ore on the surface. On Richards' farm, in the same range as Brotzman's, but farther west, surface ore is quite abundant, some of it being fibrous hematite. The next farm westward, presents the same indications.

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[1] Henry, M. S., History of the Lehigh Valley, p. 165, 1860.

[18] Rogers, H. D., Fifth Annual Report on the Geological Survey of Pennsylvania, pp. 42-43, 1841.

The local iron industry received a great impetus in 1840 owing to the successful smelting of the iron ore by the use of anthracite. Before 1840 anthracite had been used in place of charcoal, but not until 1840, when the Lehigh Iron Co. (later changed to the Crane Iron Co.) started its first blast furnace at Catasauqua, was the experiment entirely successful. To furnish ore for the furnace several iron mines were opened in the vicinity.

Within the next decade iron furnaces became numerous along Lehigh River from Coplay to Easton and most of them were run mainly, if not entirely, on local limonite ores (usually called brown hematite by miners and furnacemen), supplemented at some furnaces by magnetite ore from New Jersey. Scarcely a settlement along Lehigh River within Northampton and Lehigh counties has not at some time had blast furnaces in operation.

In 1857 the Saucona Iron Co. was organized to work the Gangewere mine in the Saucon Valley and to erect a blast furnace. The first plan was to build the furnace at the mine, but it was later decided to build the furnace at South Bethlehem, and the name of the company was changed to the Bethlehem Rolling Mills & Iron Co. Owing to financial difficulties, the erection of the furnace was not started until July 1861, and about that time the name of the company was changed to the Bethlehem Iron Co. On account of the Civil War it was not until January 1863 that the furnace was completed and put into operation. In 1868 the Northampton Iron Co., which owned large iron mines in the Saucon Valley and which was building a furnace near Freemansburg, was merged with the Bethlehem Iron Co. For many years a large part of the ore used came from the Saucon Valley. At present the company, which is now the Bethlehem Steel Co., uses no local ores.

The next furnace on Lehigh River was that of the Coleraine Iron Co. at Redington, which company was organized by W. T. Carter & Co. of Philadelphia in 1869. Two furnaces were operated for several years but are now in ruins. The company owned and operated four mines in Northampton County, three in Lehigh County, and three in Berks County.

South of Island Park along Lehigh River is the Keystone furnace, which for years obtained its ore from mines near by. The building of the furnace was started in June 1873 and it was first put in blast April 17, 1876. On April 1, 1882 it was purchased by the Thomas Iron Co., which operated it for many years.

Two iron companies have operated furnaces in the Saucon Valley. The largest operator was the Saucon Iron Co., which built two furnaces at Hellertown, one of which was put in blast on March 25, 1868

and the other on May 25, 1870. The company owned several iron mines near Hellertown and Bingen, and a few miles of railroad connecting some of the mines with the North Pennsylvania, Philadelphia & Reading Railroad. The company's properties were sold to the Thomas Iron Co. on December 13, 1884, and the furnaces were in operation almost continuously for many years. Local limonite mines furnished much of the ore at first but later, ore was shipped in from other States.

The North Pennsylvania Iron Co. was chartered in April 1869, and proceeded to build a furnace at Bingen. The furnace was first blown in on June 1, 1871. On July 8, 1872 it was damaged by an explosion, and operations ceased until October 15 of the same year. After a few weeks the stack burst, and the furnace remained idle until January 25, 1873. It then worked with little interruption until April 8, 1875, but is now in ruins. The largest amount of pig iron manufactured in one year was 10,777 tons in 1874. Nearly all the ore used came from limonite mines near Bingen.

Many persons still living recall the time when the roads in all directions were occasionally almost impassable on account of the heavy loads of ore hauled over them to the furnaces from the local mines. Mining was one of the principal occupations and at times the roads were occupied by long lines of ore wagons. At present the old mine holes that are filled with water serve as swimming holes for the boys of the vicinity or furnish excellent places for raising bullfrogs or fish. However, interest in the mining of iron ore has not been lost, prospecting for good deposits is still being carried on from time to time, and many persons are confidently looking forward to the revival of mining activity in the region.

TYPES OF IRON ORE

The iron ores of Northampton County belong to two classes—the brown (limonite) and gray (carbonate) ores of the Cambrian and Ordovician formations, and the magnetite ores of the pre-Cambrian gneisses. The two classes are sharply separated in practically all their characteristics, such as kind of ore, mode of occurrence, and origin.

The brown ores (limonite) of the region are generally known locally as brown hematite. There is some justification for this usage, as some of the ore is decidedly red on account of the admixture of goethite and turgite and in places might be confused with hematite. The limonite ores are separable into two kinds, which have been called "mountain ores" and "valley ores." Both are well represented in this county. The mountain ores occur along the slopes of South Mountain and in some of the narrow valleys east of the Saucon Valley

and are included within the Cambrian quartzite areas; the valley ores occur in the broad valleys in areas of Cambrian and Ordovician limestones.

DISTRIBUTION

Mountain ores.—The mountain ores are confined to the areas of Cambrian quartzite. Most of the mountain ore mines of the county are in a belt along the north slope of Morgan Hill. Mines in these ores have also been worked in the short, steep-sided valleys southeast, east, and northeast of Hellertown.

Mines are numerous in certain areas of the Cambrian quartzite but are lacking in others where the formation is equally well developed. The metamorphic changes that the formation has undergone locally since its deposition have determined the places where ore has been deposited. In the areas where the ore deposits occur, many of the original sandstone strata have been changed into jasperoid rocks, although certain conglomeratic strata remain practically unchanged; but in places where ore deposits are absent the formation is composed entirely of ordinary sandstones and conglomerates. It is therefore considered useless to prospect for iron ore of this type in areas where the irregular masses of yellow to red jasperoid rocks are absent in the soils.

Valley ores.—The limonite ores of the limestones are extremely irregular in their distribution. The map shows one belt of iron mines that extends in an east by north direction through Hanoverville to Hollo.

There seems to be some relation between the structural features of the rocks and the location of the ore deposits, for as a rule the largest deposits of ore are found in places where the limestones have been closely folded or faulted. As the rocks are likely to be much more shattered at the crests of closely folded and eroded anticlines, such places should be more favorable for ore deposition, and the investigations in this region indicate a relationship of that kind. In general, those places in the limestones where the underground waters have collected and flowed with greater freedom are the places where the ore was deposited in largest amount. Miners frequently remark upon the observed connection of underground watercourses and the limonite deposits. As a rule, throughout the limestone regions good wells can be procured in few places at depths less than 200 feet, and yet few good iron mines have been opened where the volume of water encountered at depths of 100 feet or even less was not an obstacle to the development.

Limonite deposits are not found in the valleys of the main streams but are common in local depressions in the general upland surface where sink-hole topography is noticeable. As the glacial deposits are usually thicker over the ore deposits than in the surrounding region it is probable that depressions existed there before the glacial epoch.

OCCURRENCE

All the limonite ore deposits of Northampton County are surficial. They are irregular in extent and either occupy pockets in the underlying rocks as much as 100 feet or more in depth, or follow certain strata that more readily yielded to solution or replacement. In the belt of iron mines along the slope of Morgan Hill certain strata were converted into iron ore more or less completely for about three miles, and the ore bodies consequently are parallel to the adjoining strata both in dip and strike. In other places, however, the ore formed irregular masses which bear little relation to the structure of the surrounding rocks, so far as can be determined. Usually, however, the greatest diameter of the ore body is parallel to the strike of the inclosing strata.

The position of the mountain ores near the base of the mountains formed of gneiss causes them in most places to have a surface cover of float rock from the higher ground, and consequently the ore appears at the surface in but few places. This cover may be so deep that the ore can be worked only through shafts.

In some places the valley ores are concealed by deep deposits of glacial material that render their discovery difficult, but most of the bodies of ore thus far worked were located by the float ore in the soil. Good ore in many mines was reached within a few feet below the surface. In some freshly plowed fields the soil in the vicinity of a body of limonite ore is a rich brown that can be easily distinguished at a distance. Most of the ore bodies in the limestone valleys have been discovered by sinking test pits in places where the soil was deeply colored and pieces of float ore were abundant. Bodies of workable ore have also been discovered by sinking test pits along the line of known deposits or in the vicinity of sink holes.

The ore has been found as much as 175 feet below the surface, which was approximately the maximum depth of the mountain ore mines, owing to the difficulty of keeping them free from water and also owing to the tendency for the shafts and drifts to be closed or rendered dangerous on account of the squeezing action of the clay associated with the deposits, which slowly moved downhill when saturated with water. It is probable that few of the bodies of limonite ore extend much below the ground-water level and that they scarcely

exceed a maximum depth of 300 feet, which is much deeper than any of the mines of the region. In many of the valley-ore mines the limonite occupied shallow basins in the limestones and solid limestone was found at depths less than fifty feet. Rock in place is now exposed in many of the old limonite pits. In the mountain-ore mines the ore became leaner or changed to ore high in sulphur in lower levels but still continued to the greatest depths reached.

The iron ore is almost invariably associated with quantities of white, yellow, or bluish-black clay formed by the decomposition of shaly strata which are interbedded with Cambrian sandstones and quartzites and the Cambrian and Ordovician limestones. Besides the clay, masses of jasperoid quartzite are commonly encountered in the mountain-ore mines, and small and large rounded segregations of black chert occur in the valley ores. The fragments of jasper represent portions of the original Cambrian quartzite that have undergone less alteration.

Within the clay the iron ore occurs either in the form of isolated masses or in rather definite veins that have a maximum width of forty feet. Even in the best ore bodies, considerable clay and ocher are present, ranging from one-third to one-fourth of the material removed from the mine. In the average mine the clay washed from the ore constituted from 50 to 75 percent of the product. The ore in the veins invariably is cavernous and contains considerable clay within the cavities.

Yellow ocher is almost everywhere associated with the ore, as would be expected, for ocher is an intermediate product between the clay and the iron ore. In the ocher the limonite has not been segregated but occurs in the form of finely disseminated particles intimately mixed with the clay.

PHYSICAL CHARACTER

The limonite ore occurs in several different forms some of which have received distinctive names by the miners, such as bombshell or pot ore, pipe ore, and wash ore.

The bombshell or pot ore consists of more or less spherical masses of limonite that range in diameter from one inch to two feet. They are geodes of limonite; many of them are hollow or filled with water and others are fairly well filled with white or drab clay or fine white to pink sand. The interior of these geodes almost invariably presents a black lustrous botryoidal surface, which in some specimens is markedly iridescent. The dark color of the interior suggests the presence of considerable manganese, and analyses commonly show this metal to be present, although the lacquer-like surface is mainly, if not en-

tirely, composed of goethite. Tiny stalactites of limonite occur in many of the geodes. The walls of the bombshells range from considerably less than an inch up to an inch or more in thickness and in most specimens show a fibrous radiating structure in the inner layers. Some of the geodes contain sand grains firmly cemented by iron oxide, but others are practically free from any siliceous particles that can be detected by the eye. In general, the bombshell ore is the highest grade ore obtained and can be readily freed from any adhering clay by washing. Many of the geodes consist largely of iron carbonate (siderite), and in a few mines the bombshell ore is called carbonate ore. Invariably, however, limonite also seems to be present, especially in the inner layers. The carbonate bombshell ore is gray when mined but later becomes brown as the carbonate changes to limonite on exposure. Some geodes have been found in which the stratification of the original sandstone or limestone is preserved in the inclosing walls.

Closely related to the bombshell ore are the large irregular masses of cellular material that form the bulk of the limonite ores. These masses are from a few inches to ten feet or even more in diameter and consist of a network of thin partitions of limonite running in every direction. The cavities usually are small, as a rule not more than a few inches in extreme length, are exceedingly irregular in shape, and are commonly filled with an ocherous clay. The walls of the cavities are coated with a firmly cemented layer of the ocher. The character of this ore renders it possible for the miners to break the large masses readily with pick and sledge.

Some of the mountain ores occur as masses of porous limonite roughly arranged in parallel layers and resemble in structure pieces of rotten wood. The layers probably represent the stratification lines of the original rocks. Tiny stalactites of limonite are abundant between the layers.

Small pieces of cellular ore in which the cavities are rectangular are occasionally found. These specimens represent the segregation of limonite in joints of the original rock, the partial replacement of the original rock, and the subsequent removal of the remainder through solution. Some of the longer tubelike masses are called pipe ore, although true pipe ore is somewhat different. In some places the original rock remains, surrounded by a shell of limonite. In the mountain-ore mines pieces of limonite inclosing sandstone are not uncommon.

In many places the original sandstone of the mountain ores seems to have been broken into angular fragments, probably owing to the contraction of the mass as it changed to jasper, which usually preceded the formation of the ore. These angular fragments have later

been cemented by limonite that was precipitated in the cavities and forms a limonite breccia. In many specimens fragments of sandstone or jasper have themselves later been replaced by limonite. In ore of this kind small particles of secondary vein quartz are more common than in the other kinds of ore, although quartz is not common in any of the limonite ores. The secondary quartz shows that part of the siliceous material removed by the solution of the original rock was precipitated in the cavities of the iron ore.

In the valley-ore mines, tubes of limonite that inclose more or less sand are common. This variety is known as pipe ore and was the principal ore mined in many places. The largest tubes are a foot in diameter, although most of them range from one to two inches. Pieces more than eight inches long are rare but as the pipes are invariably broken at each end they may originally have been several feet long.

Fragments of limonite in the form of irregular particles or plates are invariably present in large quantities. They represent broken pieces of all the kinds of ore that have been described. As the rock disintegrates and clay and iron ore are formed, there is a tendency for the entire mass to move down the slopes, which results in the breaking of the more fragile pieces of ore. The loss in bulk that takes place as the rock undergoes changes in composition also permits the downward settling of the material and the breaking of many of the masses of ore. The larger pieces of the fragmental ore are recovered in the washers, but the finer ones are lost. Ore of this kind is known as "wash ore."

COMPOSITION

Minerals associated with the ores.—The composition of the limonite ores is extremely variable and depends largely on the physical character of the material. The presence of certain minerals closely associated with the limonite also determines the composition. The impurities in the ore comprise only a small number of minerals, principally quartz, jasper, clay (kaolin), pyrite, pyrolusite, and wavellite.

Siliceous matter of different kinds can be detected in almost all the mountain ores. In some places it represents the fine grains of sand of the original sandstones or sandy limestones, in others secondary chert or jasper, and in still others vein quartz. Clay fills many of the cavities in the ore, and much of it is not removed in passing through the log washers. Very small particles of pyrite can be seen with the naked eye in some specimens, particularly in the ore from the lower levels of certain mines.

Pyrolusite is intimately associated with the limonite and is generally detected by the dark color of the ore. Occasionally dendritic crystals

of pyrolusite form a thin cover to the limonite. In general the mountain ore contains a higher percentage of manganese than the valley ore. A mass of crystalline pyrolusite from the Wharton mine of the Thomas Iron Co., two miles east of Hellertown, yielded on analysis in the laboratory of the company the following results:

Analysis of pyrolusite from Wharton mine of Thomas Iron Co., two miles east of Hellertown, Pa.

Mn	52.72
Fe	.868
SiO_2	.46
P	.046

Most of the phosphorus in the ore is probably contained as aluminous and iron phosphates, such as wavellite $[(AlOH)_3.(PO_4)_2.5H_2O]$ and cacoxenite $[FePO_4.Fe(OH)_3.4\frac{1}{2}H_2O]$. In the iron mine three-quarters of a mile southeast of Hellertown, fine, delicate, white, radiating crystals of wavellite occur within the cavities of the limonite ore. At the same locality fine tufts of golden-yellow crystals of cacoxenite are present in the small crevices of the ore and also small quantities of beraunite $[Fe_3(OH)_3(PO_4)_2.2\frac{1}{2}H_2O]$. In most of the ores, however, no phosphorus minerals can be seen, although analyses show that some are present.

Mountain ores.—Although the sulphur usually is low, some mountain-ore mines had a large amount of pyrite in the lower levels. It is probable that deeper workings may show an increase of pyrite in almost all the mines, but the decrease in the content of iron and the increased expense of mining has prevented the exploration of the lower portions of the ore bodies in most places. Examination of hundreds of analyses made by the chemists of the Thomas Iron Co., the Bethlehem Steel Co., and the Crane Iron Co. shows that the mountain ores average about 40 percent iron, 20 percent silica, 0.4 percent phosphorus, 0.2 percent sulphur, and 3.26 percent manganese. The iron content ranges from 32 to 54 percent. Very little ore was used which contained less than 36 percent iron, and a few mines have furnished much ore that ran as high as 50 percent iron. The ores are characterized by a high percentage of silica, ranging from 15 to 30 percent. The phosphorus is usually too high for Bessemer steel; in much of the ore it runs up to approximately 1 percent.

Perhaps the most distinctive feature of the mountain ores is the high content of manganese, which ranges from 2 to 4 percent in most of the mines but may run as high as 15 percent in places, and pieces of practically pure pyrolusite are occasionally found. For this reason the mountain ores have always been in demand by the furnaces making basic iron.

*Analysis of limonite mountain ores from Wharton mine of Thomas Iron Co.**

Fe	44.16
SiO_2	19.14
P	.377
Mn	2.18
Moisture	6.78
Al_2O_3	4.21

Valley ores.—The valley ores differ somewhat in composition from the mountain ores. These differences are mainly in the greater amount of silica and manganese in the mountain ores and the greater amount of magnesia and phosphorus in the valley ores. Most of the ores, after washing to remove the bulk of the loose clay, averaged slightly more than 40 percent metallic iron and ranged approximately from 35 to 50 percent.

ORIGIN

Processes of formation.—Although the limonite iron ores of the Appalachian region have been discussed in hundreds of articles, there is still no entirely satisfactory explanation of their origin. Many investigators have shown a tendency to regard all of them as having a similar origin, which is an incorrect view. Even in a single mine, evidence can sometimes be obtained to prove that limonite has been formed by the oxidation of pyrite, by the oxidation and hydration of siderite, by the replacement of limestone or sandstone, by the segregation of particles of disseminated limonite, or by precipitation in open fissures or other cavities. Under such conditions it is obvious that a theory that attributes the origin of these ores to one process of formation is not sufficient even for certain single deposits and is entirely inadequate for universal application.

The limonite ores are commonly known as residuary iron ores and are supposed by many investigators to represent the insoluble oxidized particles of iron that were originally present in limestones or shales in the form of carbonates or sulphides and were left as a residuum when the mass of the country rock was removed by solution. Such an explanation, however, disregards the concentration of the ores in somewhat veinlike ore bodies. The particles of limonite have not merely been left as a relatively insoluble residuum on the removal of the inclosing rock, but instead, in the main, they have been transported in solution and precipitated in more or less concentrated form in the clays that are plainly of residuary origin. For these reasons the term "residuary limonite ores" is likely to be misleading and is only appropriate if the ores are considered to represent materials that were once distributed through a great thickness of rocks now removed by

* Average of large number of analyses.

erosion. The ores themselves have also been dissolved, transported, and precipitated, perhaps several times.

In the discussion of the origin of the brown iron ores, three stages should be considered—the original source of the iron, the primary segregation, and the secondary concentration.

Original source of the iron.—The iron of the brown iron ores probably was present in the form of pyrite, magnetite, or some ferromagnesian silicate, original constituents of the igneous rocks that underlie all the sedimentary strata in which the bodies of ore now occur. When the Cambrian and Ordovician sandstones, limestones, and shales were deposited in the shallow waters of the Appalachian sea both pyrite and siderite were precipitated from solution to form part of these sedimentary strata. Consequently all the rocks of the region—gneisses, sandstones, limestones, and shales—have contributed material for the formation of the ore bodies. Not only have the rocks now present in the region yielded iron for these deposits, but much was also derived from a great thickness of rocks which once overlay the present strata and was removed in the long period during which the Appalachian province has been subjected to erosion. At least 10,000 feet of strata have been removed by erosion from the region since Ordovician time, and though most of the iron of these rocks doubtless was carried away, a considerable portion was dissolved and precipitated in the underlying rocks.

Primary segregation of the iron.—The most striking feature of the occurrence of limonite deposits in the limestones is their relation to channels of underground drainage. The abundance of water was a serious obstacle in the operation of almost every valley-ore mine that was more than fifty feet in depth though elsewhere in the limestone valleys wells must be sunk much deeper in order to procure enough water for household use. As these water channels are formed by the fractures in the rocks that were produced during the great earth disturbances at the ends of the Ordovician and Carboniferous periods, it is reasonably certain that the ground water has been flowing through them for millions of years.

The mountain ores also occur in regions where the rocks have been fractured and afford free passage for ground-water circulation. In every place in the region where the mountain ores have been mined, the Cambrian sandstones have been largely altered to jasper or chert. The metamorphism is believed to have taken place mainly at the end of the Ordovicion period, when the region was subjected to intense dynamic forces that resulted in the intricate folding and faulting now so well exhibited. Post-Carboniferous movements also have been ef-

fective in producing the complicated structure. Meteoric waters that passed through the deformed strata undoubtedly were heated above normal temperature and their dissolving power was increased. The grains of quartz of the sandstones were dissolved, and the material was later precipitated in the cryptocrystalline form. In the replacement there was a considerable shrinkage, as is shown by the numerous contraction cracks or brecciated form of the jasperoid rock. In some places the cavities were subsequently filled with quartz or jasper which made the rock almost as compact as it was originally, but in general the jasperoid rock is extremely porous.

The first step in the formation of the ore was the segregation of the iron that was disseminated through the gneisses, sandstones, limestones, and shales of the region in the form of pyrite and siderite. Meteoric waters that passed downward through the strata dissolved the pyrite and siderite. When these solutions reached the shattered areas in the limestones or the zones of porous jasperoid rock that rested on gneisses the water in many places ascended, just as now the deep-seated waters of the region rise to the surface along fault or fracture zones. Even in the areas where only limestones are present, flowing wells have been obtained at depths of 750 feet, which shows the tendency of the deeper waters of the region to rise under artesian pressure when a passageway is provided.

In the Cambrian sandstones the ascending solutions precipitated pyrite in part as a filling of previously existing cavities and in part as a metasomatic replacement of the jasperoid rock or the shales that were interbedded with the quartzite, especially in the upper part of the formation. So few mines have been worked to the depth where the pyrite ore still persists that little evidence of the manner of deposition of the pyrite is available. Some specimens obtained from one of the mines about halfway between Emmaus and Mountainville, Lehigh County, indicate an almost complete replacement of the quartzite, but it is doubtful whether these are typical. Instead, it is probable that the substitution of the pyrite for the jasper and shales was irregular and variable. One of the chief supports of the view that ascending waters have caused the segregation of the pyrite is furnished by the depth to which the pyrite extends. It is now found at the greatest depths explored, far below ground-water level. The level of ground water has fallen as the valleys have been deepened by erosion, and therefore it is probable that part of the pyrite was formed at much greater depths than would be possible if it were segregated by descending waters. Besides, in the almost complete absence of any organic matter in the Cambrian quartzite it is difficult to see how the precipitation of the pyrite could have been accomplished by de-

scending waters rich in oxygen, in which the temperature and pressure would have continually been on the increase. Decrease of temperature and relief of pressure were probably the dominant factors in the precipitation of the pyrite from the ascending solutions.

In regard to the valley ores, the primary segregation of pyrite by artesian waters as the first stage in the formation of the present ore bodies is less definitely known. The massive pyrite found in the lower levels of the Friedensville zinc mines and the increase of pyrite with depth in many of the limonite valley-ore mines indicate the presence of pyrite beneath the brown ores in certain places, although the data are too meager to warrant the conclusion that a zone of pyrite is everywhere present. In a brown iron ore mine near Breinigsville, Lehigh County, enough pyrite was obtained in the lower levels to be profitably marketed. In most places, however, the mines were not worked deep enough to determine whether pyrite commonly underlies the limonite ores or not. The increase of sulphur in the ore caused some mines to become unprofitable, but the excess of water and the slumping of the clay banks were the principal causes for other mines closing before a zone of pyrite was reached. Nevertheless, the facts at hand warrant the conclusion that many of the great limonite deposits of the region are underlain by considerable pyrite, which, however, may be and probably is as a rule too greatly disseminated to be of any economic importance.

Part of the precipitation took place in open fissures in the limestones, but much of it was in the nature of replacement of the rocks that constitute the walls of the fissures. This feature was plainly shown in the Friedensville zinc mines, where the limestones were extensively replaced by pyrite.

The brown iron ores are invariably associated with a large amount of clay representing the residuum of shaly strata interbedded with the limestones and sandstones. These impervious shaly beds undoubtedly, to a large degree, furnished favorable conditions for the primary segregation of the pyrite through assisting the concentrated flow of the mineralized underground waters, and the places where the shaly strata were present were therefore most suitable for the deposition of the minerals that were carried in solution.

The presence of pyrite in the lower workings in considerable quantities seems to indicate that the ores cannot have been formed entirely by descending waters that have brought the iron in solution to these places, as is generally supposed. The abundance of pyrite invalidates the explanation of other writers who believed that the ores were deposited in the Cambro-Ordovician sea as limonites or that they represent the oxidation in place of iron carbonate ores that were de-

posited as marine precipitates. There are, likewise, valid objections to the explanation proposed by Chance,[19] who believes that the ores are gossan deposits that were formed by the oxidation of pyrite which was "a mechanically transported sediment, derived from the erosion of older eruptives." On account of the instability of pyrite it could hardly be liberated from igneous rocks through the decomposition of some of the constituent minerals without itself being oxidized, and the situation of most if not all the ore bodies in regions where the rocks have been greatly shattered might also be used as an argument against this view.

Whether the carbonate ores were formed during the primary mineralization cannot be definitely determined without additional information. The carbonate ores are found in the lower levels of both the valley-ore and the mountain-ore mines in association with the limonite, but data are lacking as to their association with the underlying pyrite. Where the ascending iron-bearing solutions came into contact with limestones or encountered carbonate waters from the limestones, it would be natural to expect the formation of siderite, and in all probability part of the iron in the primary segregation was precipitated as siderite and either replaced the rocks or filled fissures just as the pyrite did. In the Wharton mine, southeast of Hellertown, the carbonate ore was less abundant in the lowest workings than it was a short distance above them, which might mean that it did not extend into the region of unaltered primary mineral deposition and thus point to its secondary character. At present it is well to consider the carbonate ores as in part primary and in part secondary, and not to attempt to say which class is the more important.

Secondary concentration of the iron ores.—The present workable iron deposits are the products of alteration of the original segregations of pyrite by descending waters carrying oxygen and carbon dioxide in solution. Some of the sulphide was changed directly to limonite, forming a spongy ore characteristic of gossan deposits; other portions were altered to limonite that was taken into solution and metasomatically replaced part of the associated quartzite or was precipitated in open spaces as stalactites of limonite; and still other portions were converted into siderite and precipitated as bombshell ore or compact rounded concretions. Numerous specimens illustrating each of these processes have been found in the vicinity of the abandoned iron mines.

The following chemical reactions illustrate some of the probable changes which took place.

[19] Chance, H. M., Am. Inst. Min. Eng., Trans., vol. 39, pp. 522-539, 1909.

$$FeS_2+7O+H_2O=FeSO_4+H_2SO_4$$
$$6FeSO_4+3O+3H_2O=Fe_2(SO_4)_3+2Fe(OH)_3$$
$$2H_2O+FeSO_4+CaCO_3=FeCO_3+CaSO_4.2H_2O$$
$$FeCO_3+H_2O+CO_2=Fe(HCO_3)_2$$
$$Fe(HCO_3)_2+CaCO_3=FeCO_3+Ca(HCO_3)_2$$
$$2Fe(HCO_3)_2+O+H_2O=Fe(OH)_3+2CO_2$$

In most places the descending waters probably deposited the iron minerals in more concentrated bodies than had been done in the primary mineralization, yet this may not have been true everywhere. In some places where large deposits of pyrite had existed, the mineral waters that resulted from the oxidization and solution of the pyrite probably were dispersed and lost.

As siderite is not stable in the presence of highly oxygenated surface waters, it has practically all been changed to limonite near the surface but still persists a short distance below the ground-water level. In many of the mines, siderite nodules partly altered to limonite can be found.

Pyrolusite occurring with the limonite has had a similar origin. It probably existed in the pyrite and on oxidation was changed to its present form. Part of the manganese has been segregated to form masses of practically pure manganese oxide, but the bulk of it is intimately mixed with the limonite.

In places large rounded masses or small botryoidal segregations of secondary chalcedony are abundant. These masses occur in the clay and may have been formed by ascending waters at the time the pyrite was concentrated or more recently by descending waters. Lack of information regarding their distribution in depth prevents any positive conclusion.

In some of the mines in the limestones there is every indication that the limonite deposits are the result of precipitation from descending waters alone, no pyrite ever having been present in the immediate locality, as the limestone floor gives no indication of the presence of deep fissures through which ascending waters might have brought pyrite. In such places the deposition of the limonite has been produced by percolating waters which dissolved the disseminated iron minerals that were present in the overlying strata and carried them as sulphates or bicarbonates until they were checked by impervious shaly strata in their downward movement and became stagnant and then gradually precipitated the iron in the form of limonite or carbonate, probably by coming into contact with other surface waters that carried oxygen in solution. Such an origin is generally believed to account for most of the limonite deposits that are so widespread in the Appalachian region. According to this theory all limonite deposits would form only close to the surface, and as they could scarcely be

expected to form rapidly, the regions where they are found must have been subject to very little erosion for a long period or else the limonite would have been removed by erosion.

During the period of stability in Tertiary time when the Somerville peneplane, so well represented in the limestone valleys, was developed, conditions were favorable for the formation of ore bodies in this manner, and no doubt many of the brown iron ore deposits of the valley-ore type were formed at that time. Similar ore bodies probably were formed during the periods of Harrisburg and Schooley peneplanation, but these deposits have been largely if not entirely removed by subsequent erosion, which has destroyed all portions of these peneplanes in the limestone valleys.

Prime[20] in his discussion of the iron ores of the region, suggested a secondary origin of a different character for some of the deposits then being worked. He says:

> The whole appearance of the mine is that of a secondary deposit and seems to point to the ore not being in place. All through the yellow clay there are fragments of rock—limestone, damourite slate, and quartzite. The two former are angular, the latter more rounded. The conclusion arrived at by the writer is that the entire deposit has been formed during the Drift period; the ore, rock and clay having been pushed down from deposits to the north or northwest and deposited here in a depression of the limestone rock.

There is no doubt that much of the limonite picked up in the fields owes its present position to transportation by the ice during the glacial epoch but it is extremely doubtful whether any workable deposits have been formed in this manner, as suggested in the passage quoted.

The clay that is associated with the limonite ore represents the residual materials left by the decomposition of aluminous and siliceous strata. These clays were formed at the same time the secondary concentration of the ore took place. In many places shaly laminæ or shale partings are interbedded with the limestones and sandstones, and these strata would yield much clay. Prime believed that the black clays had been formed from some of the overlying Ordovician black slates, which he called Utica slates. In some of the descriptions of individual mines quoted from his report on later pages, statements of this kind are made. The irregular distribution of the black clay and its occurrence in some places in detached masses beneath clays unquestionably formed from strata interbedded with the limestones and sandstones preclude such an origin. It must be admitted, however, that the formation of the different kinds of clay—red, white, drab, blue, and black—found in the mines of the region, presents

[20] Prime, Frederick, Jr., Pennsylvania Second Geol. Survey, Rept. D3, vol. 1, p. 201, 1883.

many unsolved problems. Information is lacking in regard to the original character of the beds that gave rise to these varieties of clay. At the surface these strata have been thoroughly decomposed, and there are no deep excavations to furnish the desired data.

The depth to which the clay and the brown ores extend, nearly 200 feet in several places, indicates free underground drainage. Where the rocks have been decomposed to so great depths the structural features, such as the fracture zones previously mentioned, openings between bedding surfaces caused by the uptilting of the strata, and the alteration of limestones and shales or sandstones and shales, favored the collection of the surface waters into channels and produced the localization of weathering described. The depth to which the limonite and the clays extend implies that outlets for subterranean drainage existed at equivalent or lower elevations.

As the decomposition and removal by solution of portions of the strata proceeded, the ground gradually settled downward, producing sink holes, which would still further increase the volume of percolating water through the collection of more of the rain water, which formerly reached the surface streams. When the ice sheet advanced over the limestone valleys these depressed areas were largely obliterated by the deposition of glacial debris, which is generally thicker over the iron-ore deposits than elsewhere.

The settling of the clay owing to the shrinkage of the rocks also broke the particles of iron ore, producing the wash ore described elsewhere in this report.

Method of Working

Most of the limonite mines of the limestone regions were worked by open cuts, especially in the early stages, and many of the mines of the Cambrian quartzites also were worked in that way. The great quantity of clay and the few ledges of hard rocks associated with the ore at first favored open-cut work, but as the excavations increased in depth the loose materials tended to slide into the pits after heavy rains, and shaft mining replaced the former method. In numerous places shafts have been sunk in or near old pits. Where the mines were on steep slopes, as were many of those in the Cambrian quartzite, the deep cover of hillside wash made shaft mining necessary from the beginning.

In open-cut mining the body of ore, which occurred in a more or less veinlike form, was followed, but mining was not restricted to these bodies. Throughout the mass of clay considerable wash and lump ore would be found, sufficient to justify practically everything being taken out and run through the washers for a considerable distance on

both sides of the body of concentrated ore. In this way, in some places, several acres were worked over. When a pit was first opened, horses and carts were used to haul the ore to the washer, but as the mine became deeper, inclined tracks were laid, up which the ore was hauled in small cars. In the open-cut mines of the limestone regions the limestone floor was very irregular. The rock came within twenty-five feet of the surface in many places, but elsewhere it was not reached at the greatest depths. In general, the ore is concentrated to a greater degree where the decomposition of the rocks has proceeded to a great depth, as the ground waters that followed the most open passageways accomplished both the decomposition of the rocks and the segregation of the ore.

In shaft mining the veinlike ore bodies were followed in drifts run at different levels, and stopes were raised to the levels above. Most of these bodies of ore are approximately parallel to the strike of the inclosing rocks, especially in the Cambrian quartzites, where certain layers were more easily replaced than others. Where the ore that was being followed became lean or disappeared, crosscuts were made to either side, or the direction of the drift changed in a haphazard manner. In the operation of some mines it was assumed that more ore would be found by drifting in a certain direction, and if this surmise proved incorrect efforts would be made to find ore in another direction. Pockets of good ore were thus likely to be located after several attempts, and at the same time a few lumps and small fragments of ore would be found while driving the exploratory drifts.

The loose clay through which the shafts and drifts were driven may be said, with little exaggeration, to have been in constant motion from the time mining started until all the openings were filled by caving after mining ceased. Shafts were abandoned on account of squeezing, which pushed them out of plumb, and drifts tended to close through the pressure, which at times became so great that large timbers were broken or shoved out of position. In most mines it was necessary to timber both shafts and drifts very carefully, and the close timbering prohibited any examination of the occurrence of the ore except at the working face.

In most mines there were no ore chutes or loading pockets, as the activity of the mines was of too short duration to warrant their construction and also the great amount of clay present would have prevented the ore from running through them. In some mines the ore was loaded in buckets that were placed in a small car, which was then pushed to the bottom of the shaft and hoisted. In other mines small cars were used without the buckets.

The quantity of water encountered was a serious obstacle to the mining in almost every mine that exceeded fifty to seventy-five feet in depth. Cornish pumps were used in almost all the mines, and the water was used in washing the ore.

The mining equipment was never elaborate, because of the character of occurrence of the ore, and the output of any particular mine was consequently small. It is doubtful whether the output of any of the mines averaged more than 35 tons a day, and in most of them the average output was less than half that quantity.

PREPARATION FOR MARKET

The large amount of clay invariably associated with the limonite ore necessitated washing most of the ore before it could be shipped to the furnaces. In some mines masses of fairly pure ore were obtained that were practically free from adhering clay, and these were ready for shipment as mined, but this material was exceptional.

In the washing process several modifications of the common log washer were used. In its simplest form this device is merely a log or shaft to which are attached, in a spiral arrangement, iron plates that project a few inches. This log, which can be rotated, is set at an angle and surrounded by a trough, into which the mixture of ore and clay is dumped. Above the trough runs a water pipe or small trough with numerous perforations through which the water passes to mix with the clay and ore. The ore and the associated clay are dumped into the lower part of the trough, and the log is rotated to carry the large particles upward to the end of the trough, where they fall on a platform, while the water carries the clay in suspension to the lower part, where it flows into wooden troughs, usually supported by trestles, that convey it to a settling pond.

If the clay adheres very firmly to the ore it may become necessary to reverse some of the teeth or plates in the log in order to retard the passage of the ore and give them more opportunity to loosen the clay.

In the washing process pieces of chert or other rocks remain with the ore and must be picked out by hand, and many small fragments of ore are washed away by the water.

Most of the mines yielded enough water for washing the ore, but at times some of them had to obtain additional water from wells or near-by streams. In some places the comparatively clear water from the settling ponds was drawn off into another basin and again pumped to the washers.

The daily average of ore handled by a single washer was never large but ranged from 15 to 35 tons.

Economic Considerations

If a region where iron mining was once one of the principal industries gradually undergoes a change by which all the mines are closed and yet the iron-manufacturing industry still continues, the natural conclusion would be that the iron ore deposits had been exhausted. In Northampton County, however, where eighty-four limonite mines are known to have been worked and at present none are in operation, other causes have contributed to the existing situation. Many of the mines were worked out or abandoned because the ore was too lean, but many of them were closed for other reasons, and it is not improbable that as much ore still remains in the ground as has ever been mined. Many of the mines when closed had as much ore in sight as at any preceding period, and undoubtedly there are numerous deposits that were never worked. When the fields are freshly plowed many promising places for prospecting can be distinguished by the brown color of the soil and the fragments of float ore, which favor the conclusion that some ore deposits have never been developed.

In the early days many of the iron companies that operated furnaces acquired ore properties which they either worked or leased under the arrangement that all the ore would be sold to the furnaces at current prices. The royalties paid ranged from twenty to fifty cents a ton. In addition, independent companies acquired ore properties and engaged in iron mining and always found a ready market for their ores. In recent years, however, a great change in the iron industry has resulted in closing most of the small independent furnaces and a concentration of the iron business in a few large companies. The disposal of the pig iron made by the small independent furnaces has become increasingly difficult, and most of them have had to close. The larger companies found so many objections to the local brown iron ores that mining continued to decline until all were closed.

Perhaps the chief objection to the local brown iron ores is the variability of the supply. In winter the severe weather prevented open-cut mines from operating, and the conditions of the roads at times interfered with the delivery of the ore. No concern that uses a large quantity of ore wishes to contract for a supply that is so uncertain.

The variation in composition was also a drawback to the utilization of the local limonite ores. Both the iron content and the amounts of silica and phosphorus were extremely variable and hence objectionable. The ore averaged too high in phosphorus for Bessemer ore, and none of it was high in iron. The average limonite ores of the district contained only a little more than 40 percent of iron. Under such conditions it was inevitable that high-grade iron ores low in phos-

phorus, such as the Lake Superior ores, should replace the local ores when improved transportation facilities permitted competition.

The mine operators also encountered difficulties in the profitable operation of their properties because of the increased cost of labor and the additional cost of pumping the water as the mines became deeper. The result was that many firms hesitated to open new mines when it became necessary to abandon their old ones and decided to disband. Conditions are not now sufficiently favorable to attract new capital to the iron-mining industry.

The future of the mining of brown iron ore in this region is problematic, yet there is reason to believe that at some time mining will be actively resumed, although this will be brought about only by the exhaustion of richer ore deposits of other regions which now supply the local demand. Thus the mining of brown iron ore will not be an important industry in this region for many years, as the Lake Superior, New Jersey, and foreign ores will long continue to replace the local ores. The local operations were necessarily small on account of the manner of occurrence of the ore and so could not compete with operations in those regions where mining can be done on a very extensive scale.

Descriptions of Individual Limonite Iron Mines

All of the iron mines of the county have long been closed and very little information can be obtained by visiting the localities. On the dumps and in the mud-dam deposits one can see the character of the matrix, generally vari-colored clays, and occasional pieces of ore and associated rocks. In a few places the wall rocks are visible. Around most of the limonite ore mines in the Hardyston formation are numerous fragments, or even large masses, of taffy-yellow or brown ferruginous jasper or jasperoid.

In view of the frequent requests for information concerning individual mines, such data as could be secured is here given. Most of the mines were in operation when Prof. Frederick Prime worked in the region during the field seasons of 1874-1878 and in his reports he gave brief descriptions of certain mines. These are quoted here, together with occasional additional notes by the author. Numerous objections might be offered to some of Prof. Prime's statements but they are quoted as published. He commonly refers to the jasperoid rock associated with "mountain ores" as "flint" and also speaks about "Utica" shales as being the source of the black clays. Likewise he uses the term "Potsdam" for what we now term "Hardyston" and calls sericite, "damourite." He also believed that all the limonite ore bodies had been formed in the limestones.

The numbers used refer to the numbered mines on the map. Lack of descriptions for certain mines is explained by complete lack of any worth-while information.

MINES IN THE CAMBRO-ORDOVICIAN LIMESTONES[21]

2. Abraham George's mine.—"Leased by the Saucon Iron Co. This mine is lying idle and is full of water. The sides are too much washed to see anything of the nature of the deposit, further than it occurred associated with a black damourite slate or shale, which is probably Utica shale, judging lithologically from the character and position of identically the same shale in Lehigh County near Breinigsville. This shale is full of pyrites, which take fire on exposure, owing to their oxidation, and set fire to the carbon in the slate."

The excavation is approximately 200 feet long east and west, 90 feet wide, and 40 feet deep. There seems to have been some underground workings. No rock is exposed in the sides of the pit, but limestone appears in a small pit south of the large openings. Water from this pit was once pumped to the mill of the Bath Portland Cement plant.

3. William Chapman's mine.—"When visited, about 3 to 10 feet of stripping had been removed and there the pit presented a promising appearance. The mine had not been developed sufficiently to say whether there was a large body of ore or not. A shaft had been sunk to the depth of 65 feet, which was said to be all the way down in solid ore, but this statement is probably incorrect. The well for water had been sunk down 125 feet. At a depth of 30 feet limestone was struck and going through this, ore was said to be found underneath it (?). The ore is mostly of the bombshell variety, and inside of the hollow bombs white (damourite) clay frequently occurs, but at the depth to which the mine had been excavated no white clay was to be seen; an exception in this respect to the usual occurrence."

4. Aaron Lerch's mine.—"Leased by the Crane Iron Co. In this mine black clay (decomposed Utica shale) is found in which there is a deposit of red ore (so-called "red rock ore"); the clay occurs beneath a small deposit of white clay, over which lies brown hematite in which white and gray clay occurs sparingly. The red ore also occurs in the bottom of the mine underneath the black clay. The sides of the mine were very much washed and it was difficult to see much of the nature of the deposit."

This is one of the largest open pits of the region. It is very irregular in shape and about 1,600 feet in width at the widest part. At one place limestone is exposed in the bottom of the pit.

[21] Prime, Jr., F., Pennsylvania Second Geol. Survey, D3, vol. 1, pp. 196-203, 1883.

A typical analysis of this ore by James Gayley in 1878 gave the following results:

Fe	43.59	SiO_2	23.51
Mn	1.34	P	.381
Al_2O_3	2.36	S	trace
Ca	2.15	Water	7.69
Mg	.62		

7. Henry Goetz's mine.—"Leased by the Coleraine Iron Co. This is one of the oldest mines in the county and was finally abandoned in 1877 as being worked out. When visited in 1875-1876 the bottom was full of water and ore was being taken out near the top at the northern end, where a little red ore was left. As seen close to the bottom the ore occurs in and above a black clay (Utica shale), which containing a good deal of pyrites—perhaps marcasite—oxidizes rapidly on exposure and the surface is covered with an efflorescence of sulphate of iron. A little reddish sandstone was seen on the dump, but could not be found on the sides of the mines, although carefully searched after. Over the black clay there occurred in spots heavy bodies of white clay, in some places containing ore, in others none whatever. It is probable that the Utica shale seen here is a remnant of the period when the whole of the limestone was covered by the slates (No. III) and that being caught in a synclinal of limestone it was preserved from erosion at the time when the great body of slates was washed away. Many thousands of tons of ore have been taken from this excavation and it is a curious coincidence that the mine should have been exhausted just about the time that its aged owner died."

The excavation covers several acres and is one of the largest mines of the county. The pit is now about 75 feet deep. The ore from this mine averaged 43.59 percent iron and 23.30 percent silica.

This mine was one of the largest in the county and one of the few mines from which statistics of production can be obtained. Practically all the ore went to the Crane Iron Co. at Catasauqua, from whose books the statistics were obtained. The annual production ranged from 250 tons in 1870 to 4,941 tons in 1845, and the total production from 1841 to 1888 was 98,486 tons.

At the present time (July 1938) some of the ferruginous clay with tiny fragments of limonite of the mud-dam deposit of this mine is being excavated and hauled to the Penn-Dixie No. 4 cement plant for the manufacture of the special high-iron cement.

8. Gernert's mine.—"This has not been worked for some time and its sides are much washed. At one point in the mine there is a dark liver-brown clay (Utica shale) containing glistening particles of pyrites. On the dump there is a little white clay."

9. Milton H. Kohler's mine.—"On the north side of this excavation there is a heavy deposit of white clay coming to the surface; the pit being chiefly worked at the west end, where there is a good show of ore, a good deal of which is of the bombshell variety; this occurs embedded in seams of white clay. Close to it there are limestone boulders, formed by the dissolution of the limestone, containing thin beds of hydromica slate. The white clay seems in part at least to have been formed by the solution of limestone containing damourite."

12. Simon Ritter's mine.—"This is not being worked at present. On the south side of the mine occurs limestone, much waterworn, dipping S. 38°, E. 34°, this being the only certain dip, although there are several points in the bottom of the mine where the limestone appears. Close to this dip there is a little white clay but not in any abundance. It is possible that the ore has here been washed into a depression of the limestone and was not originally deposited there; in which case ore need only be looked for in the sides and not at any great depth. One very important fact militates against this view, and that is that in an abandoned mine on the opposite side of the road, now filled up, there occurs black clay (Utica shale) containing great lumps of iron pyrites, which turn on exposure to sulphate of iron and effloresce. This would tend very strongly to prove that the ore of both the mines is in place, and the limestone is the underlying Trenton limestone (No. II), in which no further search for ore need be made. There also occur large flints associated with the iron ore."

14. William Ritter's mine.—"This is not being worked, and the machinery has been removed. This deposit is apparently confined to the surface and is not in place. It looks as if the ore had been washed in during the Drift period, and it is associated with pieces of flint and boulders of limestone. The sides are much washed."

20. Solomon Hummel's mine.—"At this place only the stack for the washer has been erected and 5 or 6 shafts sunk within a diameter of 50 feet. There is a great deal of large lump ore at the mouth of each shaft, so that the locality presents a promising appearance."

21. Samuel Schortz's mine.—"This has not been worked for some time, so that as usual in such cases the sides are much washed. In the most eastern part of the pit there is a little white clay on the north side, containing fragments of damourite slate, but this is too little exposed to justify any conclusions. In the most northern part of the mine white clay again appears, which is apparently stratified; and below this, yellow clay containing angular flints, which also apparently occur in the white clay; but the white clay here contains a good deal

of yellow clay—also plastic—disseminated through it, so that when moistened the whole presents a yellow appearance. As this part of the pit is inaccessible it could not be viewed very closely. At the east and north end there is an abundance of ore distributed through the yellow clay."

22. J. Beck's mine.—"Leased by F. Jobst. This has not been worked since 1873. But little could be seen on this account, but the whole deposit looked as if it was a secondary one and not in place. A good deal of ore has been taken out, however, which is not often the case with deposits of a secondary character."

23. William G. Beck's mine.—"This has not been worked since 1873. The west end is inaccessible on account of water. The ore apparently occurs stratified in white clay, with white clay over it. At this mine the white clay comes within 6 inches of the surface and is about 15 to 18 feet thick, and there are alternate layers of ore and clay about 12 feet thick. From the small exposure it was impossible to arrive at any conclusion as to whether the ore was in place or was a secondary deposit."

24. John Lawall's mine.—"Leased by the Crane Iron Co. This has not been worked since 1874. In the middle of the north side a single spot of white clay is visible. In places small fragments of slaty limestone containing damourite and small boulders can be seen. It looks like a secondary deposit. The ore was found to be so unsatisfactory that work was stopped at the mine in the fall of 1878."

Joseph Hunt, assistant superintendent of the Crane Iron Co., furnished the following partial analysis made by Mr. James Gayley, the company's chemist:

Silica	24.62
Lime	1.74
Manganous oxide	2.92
Metallic iron	42.84
Phosphorus	0.431

27. Gernert & Heller's mine.—"Has not been worked since 1874. On the washed sides are small pieces of fresh and partly decomposed damourite slate and iron. The former is of a gray color. There are numerous pieces of quartzite both round and angular from the size of a large watermelon to very small pieces. The ore on the dump is much of it very light, and the large lumps in some cases contain breciated damourite slate, as if this had been cemented together by the hydrated ferric oxide."

29. Dr. B. C. Walter's mine.—"The main excavation has not been worked since 1874 and was much washed. In 1876, when visited, new shafts were being sunk. These had in some cases struck white clay,

with limestone below it, but very little ore being met with. The outlook when visited was not very promising.''

31. Thomas Richard, Jr. mine.—''This consists of a tract of several acres, covered with ore pits and surface excavations. The ore apparently only occurs in surface soil, and does not extend to any depth.''

32. Messinger & Woodring's farm.—''Here several shafts have been sunk, which are now closed. The ore at the mouths of these is abundant and the appearance is promising.''

33. M. Young's mine.—''This has scarcely been developed, beyond sinking a well and commencing to erect machinery.''

34. Samuel Lerch's mine.—''This was formerly leased by the Coleraine Iron Co., who took out about fifty tons of ore and then abandoned it. The excavation is now almost filled up, and is overgrown with underbrush. The ore was taken out of drift and surface soil. There seems to be a good deal of ore in the surface of the field; but is is very questionable whether it would pay to wash the surface soil for it.''

35. Bahl mine.—This was one of the largest iron mines in the Saucon Valley. It is very close to the Lehigh County line. Some smaller openings are in that county. The excavation covers about two acres and is said to have been about 100 feet deep. It is now filled with water, said to be about thirty feet deep, and is used as a private swimming pool.

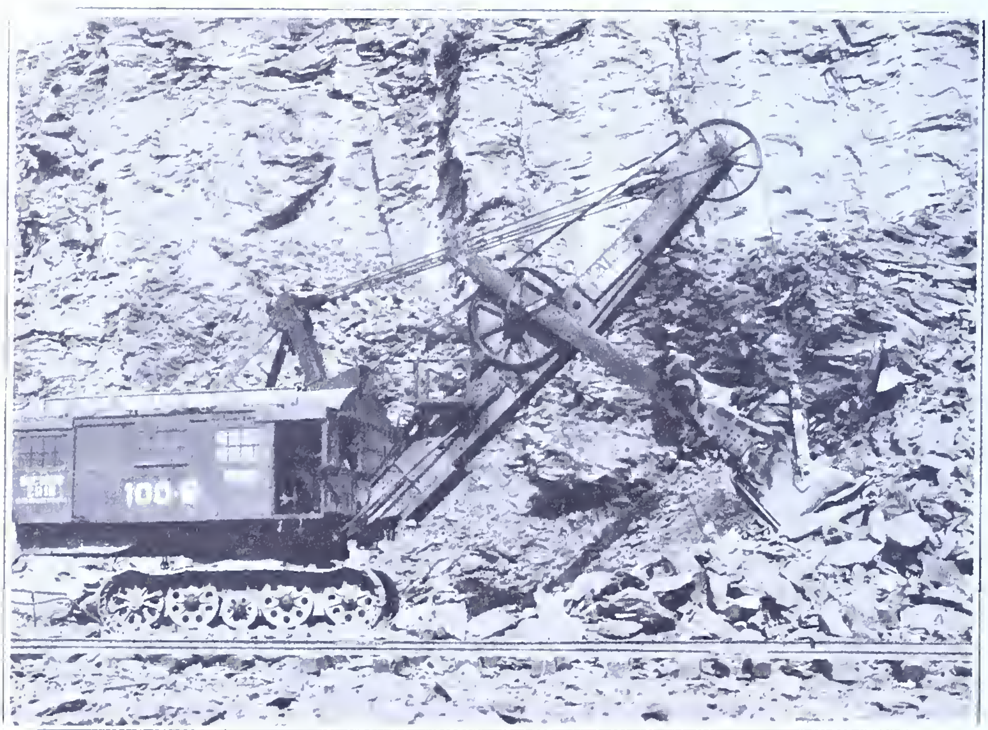
The ore mined averaged about 42 percent iron. The ore is reported to have occurred largely in rather definite veins (?) or bands about ten feet wide and was marked by the abundance of the bombshell ore. Even now one can easily find many of these hollow geodes, ranging in size from a few inches up to a few feet in diameter, as they are exposed from time to time by the erosion of the clay banks. Some are reported to have weighed as much as 200 pounds. Large and small pieces of silicified limestone were encountered in the digging, which was done entirely by pick and shovel. A considerable amount of carbonate ore is said to have been associated with the limonite.

It is estimated that altogether as much as 500,000 tons were obtained here. The date of the first work is not known. On March 1, 1856 leases on the Bahl and Gangewere properties were purchased from George Probst and Charles Wittman by the Thomas Iron Co. for $15,520. The ore was mined on a royalty, which varied from 25 to 50 cents a ton. Most was credited with the higher rate.

At different times the mine was worked by the Thomas Iron Co., the Bethlehem Iron Co. and the Coleraine Iron Co. After these companies ceased to work the property a Mr. Beidelman carried on some

PLATE 22.

A. Old limonite iron ore pit. Bahl mine, Bingen.



B. Face of quarry of Universal Atlas Cement Co. showing manner in which the cement rock breaks.

work by running short tunnels into the banks above the water level.

One of the mud-dams was on the south side of Saucon Creek. Later some of the material was dug from it for paint and still later it was worked extensively for the manufacture of brick.

MINES IN THE HARDYSTON FORMATION

38. In the southwest corner of Camels Hump a small amount of iron ore was once mined. This locality later proved to be more valuable for umber and is more fully described on a later page under "mineral pigments."

39. One mile southwest of Seidersville a few pits have been dug in search of iron ore but evidently only a small amount was obtained. The dense vari-colored jasperoid rock thrown out in the diggings indicates a somewhat unusual phase of the Hardyston quartzite.

40. Bachman mine.—The Bachman mine was opened in 1887 and worked for about five years. About 15,000 tons of good ore were taken out. The ore became lean, and the mine was abandoned. The great masses of yellow chert in the east part of the pit show conclusively that the ore was formed by replacement of Cambrian quartzite. Some of the ore contains considerable wavellite and cacoxenite, but so far as known no objection was ever raised on account of the phosphorus in the ore.

41. Kauffman mine.—The Kauffman mine was similar to the Bachman mine. It was worked by the Crane Iron Co.

43. Blank mine.—The Blank mine was operated intermittently for about five years and was closed in 1888. The ore was of good quality and was high in manganese. The vein was fairly thick, but the mine failed to pay because of poor equipment.

44. Wharton mine.—The Wharton mine, located about two miles east of Hellertown, was first opened by George Wharton in 1852, who worked it as an open pit for several years. The mine was abandoned and no work done until 1872, when it passed into the possession of the Saucon Iron Co. It was then reopened and worked for about twelve years and then again abandoned, as it could no longer be worked profitably by the open-cut method. In 1884 the Thomas Iron Co. purchased the property and at once began to sink a shaft. It was worked more or less continually until 1910, when it was finally abandoned, because the old shaft had been forced out of plumb by the pressure of the clay that slipped down the slope and it was not thought advisable to bear the expense of a new shaft.

The ore was in yellow, white, and red clays segregated in veinlike bodies five to ten feet wide, which in general headed eastward, parallel to the direction of the valley. At the 150-foot level one of these

ore bodies, which had a high angle of dip toward the mountain, was traced for about 1,100 feet. The ore also was found in large and small masses irregularly disseminated throughout the clay. Great masses of chert, some of which were four feet in diameter, were rather common in association with the clay and ore. A map of the mine workings showing the relation and direction of the main ore bodies was published in the Allentown quadrangle atlas.

The ore was high in manganese and was consequently always in demand. A large number of analyses shows that the ore contained an average of about 43 percent iron, 19 percent silica, 4.21 percent alumina, 2.18 per cent manganese, 0.377 percent phosphorus, and 6.78 per cent moisture. This mine was one of the very few limonite mines of the region from which shipments of carbonate iron ore were made. This ore is described below.

The Wharton mine has probably yielded a larger production than any other limonite mine in the Cambrian quartzite of the county. The total production seems to have been more than 200,000 tons. Statistics for only the later years in which the mine was worked are available.

Production of Wharton limonite mine

Year	Tons	Average iron content	Year	Tons	Average iron content
1890	498	57.70	1905	3,405	38.90
1900	2,616	53.02	1906	4,315	37.59
1901	6,147	50.59	1907	3,478	38.36
1902	2,074	42.56	1908	4,833	40.91
1903	2,096	42.85	1909	5,194	42.17
1904	6,141	37.26	1910	3,986	42.03

In 1901 in addition to the limonite 252 tons of carbonate iron ore were shipped and in the following year 104 tons.

45. Koch mine.—The Koch mine was an open-cut mine a short distance east of the Wharton mine. It was extensively worked first by the Saucon Iron Co. and later by the Thomas Iron Co. The main body, which was almost flat, had a width of two to three feet but the larger part of the product of the mine consisted of "wash ore" that was distributed through the clay.

The ore was low in iron, averaging only about 31.94 percent and 0.927 percent phosphorus and 2.48 percent manganese.

During the last period of operation, from 1902 to April 15, 1907, the mine produced 20,753 tons of ore, all of which was hauled to the Hellertown furnace.

46. Emery or Beatty open cut mine.—This mine adjoins the Koch mine on the east and contains the same kind of ore. The ore was high in phosphorus, averaging about 1 percent. The open cut and shaft together produced about 20,000 tons of ore. The mine was closed

in 1890. Pebbly Cambrian quartzite, which strikes N. 40° E. and dips 78° NW., crops out on the south side of the pit.

47. Emery or Beatty mine shaft.—This shaft, about fifty feet deep, is some distance east of the open pit. Good ore was obtained.

48. An old shaft mine, worked by Laubach & Riegel.

49. This shaft mine was worked for thirteen years by Dr. Madden. The workings have now caved, and the size of the pits formed shows that a large amount of ore was mined.

50. Wassergass iron mine.—The mine is unique in that about fifteen feet of coarse pebbly sandstone, which dips to the north at an average angle of 75°, forms a distinct footwall. The ore was formed by the replacement of certain layers of the quartzite and scarcely affected the adjoining strata. The ore was mined on both sides of the road.

51. Extensive workings are indicated by the size and depth of the old pit. The Crane Iron Co. worked the mine. One shaft was 67 feet deep.

53, 54, 55. This group comprises a line of old workings that seems to indicate a persistent ore body that was rather closely confined to a definite horizon in the Cambrian quartzite. As the rocks dip steeply to the north and strike parallel to the hill the old workings appear as a wide and deep trench along the side of the hill. The ore is said to have been found in decomposed slate and clay. The mud-dam deposits from these mines are dug and used for building sand.

56. Thomas Richard's mine.—"In the open cut this is only worked in the east end, where there is a good body of ore, which seems to be cut off further east by white clay. The ore occurs apparently instratified in the white clay. To the west a shaft has been sunk down 107 feet to the ore. In going down a body of damourite slate and clay was struck, which at a greater depth turns into a blue clay. Underneath the ore there is said to be black dirt, but none could be seen. The bed is said to be 27 to 40 feet thick, but this had to be taken on hearsay evidence, as the mine was so closely timbered that it could not be measured. East of this another opening has been made in the roadside, but so recently that only stripping was being taken out and washed."[22]

57. Richard's mine.—"Leased by the Glendon Iron Company. This is worked by open cuts 6 to 8 feet deep. But little is being done here, and the sides are so washed as to show nothing of the nature of the ore deposit. It seems, however, to be stripping and not a true bed."

[22] Prime, Jr., F., Pennsylvania Second Geol. Survey, Rept. D3, vol. 1, p. 195, 1883 Following quotations, idem. pp. 193-197.

58. Mary Brotzman's mine.—"Leased by Kichline. The ore occurs in damourite slate, somewhat decomposed, but scarcely pays for washing, as there is so little of it. The cut is an open one, only 8 feet deep, 2 feet of which are stripping. At the west end there is ore in the bottom of the cut. Thin streaks of black oxide of manganese occur in the face of the working, prettily crystallized. When the mine was visited, the workmen were carefully washing and picking this out as being injurious to the ore, and were much surprised at being told that by leaving it in they improved the character of the ore."

59. Mary Brotzman's mine.—"Leased by the Glendon Iron Company. At one point of this working there are old drifts which are now being worked by an open cut. In this, flint, ore and clay are all mixed up together, owing to the old underground workings, which having crushed together, caused the entire material to roll together, and thus made it impossible to see anything of the original nature of the deposit. Nearer to the road there are two shafts from which ore is being taken."

60. Mary Brotzman's mine.—"Leased by Pfeifer & Co. This is an open cut containing alternate beds of dark brown and light yellow clay, somewhat plastic in character—probably decomposed damourite slate—and containing pieces of ore. There is no regular bed, the material mined being only surface soil and sub-soils. It is very probable that the clay and ore have been washed down from the beds higher up the hill side to their present position. Flint occurs in the clay with the ore. The darker colored clay owes its color to the presence of a little oxide of manganese. The beds have a dip of N. 72° E., 17°, conforming to the slope of the hillside."

61. Joseph L. Brotzman's Heirs' mine.—"Leased by George Unangst, was just being opened when visited. Nothing could be seen except stripping, which was being washed. On the surface at the north side only clay could be seen; in the south end of the opening there was a foot and a half of white clay, containing fragments of ore, but no regular bed."

62. Mary Brotzman's mine.—"Worked by Kichline. A shaft has been sunk 64 feet to the upper bed, which is said to be 3 to 4 feet thick."

63. Jacob Crawford's mine.—"Worked by Charles Kichline & Co. In past times ore has been sent from here to the Glendon Iron Co., and the Keystone Furnace. It is said that there are two beds of ore here. A shaft has been sunk 18 feet into the top bed and it was thought the owners would have to go down about 60 feet to strike the main bed below. The top bed is about 6 feet thick and contains plenty of lump ore. There was but little white clay in the

shaft with the ore. A little lower down the field, they struck the ore in an abundance of white clay. There was no water in the shaft, nor had any been struck. In a now abandoned shaft 100 feet west of the present one the miners said that limestone had been struck at a depth of 70 feet, but that it was not solid and there was ore underneath it. As this was done several years ago, there may be some error about this on the part of the workmen.''

64. Daniel Boyer's mine.—''Leased by Reuben Nolf. This mine had not been worked for some time prior to the fall of 1877, when visited. A few days before work had been recommenced and a shaft sunk to the depth of 45 feet. Thus far but little ore has been found, and it was proposed to sink the shaft still deeper. The ore occurs in an abundance of white clay resulting from the decomposition of damourite slate. Still further to the west were abandoned ore diggings; so far as could be learnt but little ore having been found in the shafts sunk. Close by, Daniel Boyer has a clay pit which from its brownish color is at times used in the manufacture of paint.''

65. William Hahn's mine.—''This mine is situated in an arm of limestone, which extends up a trough of Laurentian rocks south of Glendon. The mine is not worked, the owners say on account of the large quantity of water; but the general structure of the rocks and soil lead to the opinion that the ore at this point is not present in any large quantity and the beds that are present must be thin.''

66. Enoch Woodring's mine.—''This is leased by the Glendon Iron Co., who are reopening it. When visited it had been temporarily abandoned.''

67. Glendon Iron Co's. mine.

68 and 69. Adam Hahn's mines.

70. Heckman Estate's mine.

71. Sampson & Sitgreaves' mine.—''Kenneth Robertson, Esq., Assistant Supt. of the Bethlehem Iron Co., analyzed the ore from this mine in 1874 and found:

	I	II
Ferric oxide	73.14=51.2 p. c. iron	71.47=50.03 p. c. iron
Oxide of manganese	0.44	6.41
Phosphoric acid	0.58=0.25 p. c. phosphorus	0.56=0.24 p. c. phosphorus
Silica	7.58	3.57
Alumina	5.82	4.50
Lime	0.21	0.00
Magnesia	0.14	0.00
Water	12.37	13.71
	100.28	100.22

I. is from the upper shaft. II. is bombshell ore. These analyses are so rich in iron that it is probable the material analyzed was from picked samples."

72. Joseph Sampson's mine.
73. Miss Miller's mine.
74. John Woodring's mine.
75. Glendon Iron Co.'s mine.
76. George Seibert's mine.
77. Mrs. Lewer's mine.
78. James Hess' mine.
79. George Seibert's mine.

In addition to the numbered mines located on the map there are several other mines in this band along the north side of Morgan Hill. A few years ago one of these mines was reopened and for a time worked for ocher and the iron ore discarded.

80. This mine is in the northwest side of Elephant Rock Mountain. "Charles Walters' mine; is worked by the Durham Iron Co. The ore is extracted by underground workings, the shaft being 60 feet deep down to the ore."

81. Joy's (Ivy) mine.—"These are mined by underground excavations, and were not being worked when visited."

82. Raub and Lerch's mine.—"But little ore was being mined when this pit was visited, owing to a scarcity of water. Shafts have been sunk through the overlying soil and clay to the ore, which apparently lies irregularly, as in some cases it comes within 15 feet of the surface, while in others it is only struck at a depth of 100 feet. The miners stated there are three beds, the one worked occurring between two lean ones, which it does not pay to extract. The ore occurs in white or gray clay, resulting from the decomposition of damourite slate."

83. Joy's (Ivy) mine.—"Here there are two shafts which were not being worked when visited. The bed was said to be 50 to 75 feet below the surface. The ore occurs in damourite slate and clay, and a number of pieces of the slate laid on the dump."

84. Stout & Riegel's mine.—"This locality was worked for a short time by the Coleraine Iron Co. and then given up. Nothing of the nature of the ore-deposit could be seen, but the proprietors said there was a great deal of ore present.

"The peculiarity of this locality is that magnetic iron ore occurs within a short distance of the brown hematite."

IRON CARBONATE (SIDERITE) ORE

Considerable iron carbonate ore occurs in the lower workings of many of the limonite mines, both in the limestones and the quartzites, and its occurrence and origin have already been discussed. It is well, however, to call attention specifically to the importance of this class of ore in Northampton County, for it has been ignored by many persons who have studied the limonite deposits of the Appalachian region. It has been found in almost every place where mining has been carried on within recent years and exposures are good.

The iron carbonate ore is gray and occurs mainly in the form of extremely dense, tough, rounded concretions, the largest of which are six inches in diameter. Bombshell carbonate ore in which the cavity is filled with white clay also is common. On exposure to the air the ore changes to limonite and the nodules or bombshells readily crumble.

Most of the carbonate ore as mined was associated with so much limonite that it was shipped as ordinary ore. A few mines, however, made occasional shipments of carbonate ore. The Wharton mine, southeast of Hellertown, reported the shipment in 1901 of 252 tons of carbonate ore that averaged 36.74 percent iron and in 1902 of 104 tons. A complete analysis of carbonate ore from this mine is quoted below:[23]

Analysis of iron carbonate ore from the Wharton mine.

[A. S. McCREATH, Analyst]

Protoxide of iron	54.385
Sesquioxide of iron	1.071
Protoxide of manganese	3.254
Protoxide of cobalt	.010
Alumina	1.457
Lime	.540
Magnesia	.540
Sulphuric acid	.112
Phosphoric acid	.263
Carbonic acid	35.340
Water (by difference)	.923
Insoluble residue	2.105
	100.000
Iron	43.050
Manganese	2.521
Sulphur	.045
Phosphorus	.115

MAGNETITE IRON ORES

Magnetite is widely distributed throughout the basic pre-Cambrian gneisses of the county as a rather abundant rock-forming mineral. Locally it is segregated in the form of iron ore, which can be picked up as float rock in hundreds of places on South Mountain. There are scores of pits in the metamorphic rocks where prospectors have tried to locate veins of magnetite ore, and specimens about these openings commonly indicate the presence of some good ore, though it may be of no commercial importance. Also after heavy rains patches of magnetite sand derived from magnetite-bearing rocks or magnetite veins are commonly seen in the gullies on the lower slopes of the mountains that are composed of gneiss. Reports are current that magnetite mines were operated in numerous places in the county where at present no data can be obtained.

[23] Pennsylvania Second Geol. Survey, Rept. MM, p. 188, 1879.

Little more than prospect pits have ever been discovered in the gneisses of Northampton County. Two small excavations have been found on the south slope of South Mountain about one and a half miles northwest of Hellertown (87 and 88) and another one on the western nose of the mountain south of Freemansburg (86). A pit about one mile south of Lower Saucon Church (89) revealed a vein of ore about two feet thick but of no commercial importance.

On his 1878 map Prime locates a mine near the summit of Morgan Hill (85) about a mile from the Delaware River which was owned by J. A. Conklin. This is probably the mine that M. S. Henry, in an unpublished manuscript, says was worked between 1795 and 1800. He says the vein was five to six feet wide and was worked to a depth of 120 feet. The ore was hauled to a furnace in the lower part of New Jersey.

Copper

Throughout the eastern United States the rocks of Triassic age in many places contain traces of copper. Many of these Triassic copper deposits have been worked, particularly in Colonial times, but very few operations have been successful. In Northampton County, copper minerals occur in two places, and both localities have been prospected. One of the deposits is one mile south of Leithsville on the Lehigh-Northampton line and the other about the same distance southeast of Leithsville on the Bucks-Northampton line. A few years ago they were investigated by James Fisher, of Bethlehem, who dug several trenches and shallow shafts but did not succeed in discovering any ore that was commercially valuable.

In both localities the minerals, associated rocks, and manner of occurrence are similar. The ore-bearing rock is a conglomerate that is loosely cemented with red to gray clay or shale. The pebbles have a maximum size of four inches, are well rounded, and consist of quartzites, limestones, and shales. The copper is in the form of malachite and occurs as a thin coating that surrounds the quartzite and limestone pebbles. It has in part replaced some of the cementing material that was formerly present but in the main has been formed by precipitation in the pore spaces of the conglomerate. In some specimens the coating of malachite about the pebbles is a quarter of an inch thick, but usually it is thinner.

As the copper-bearing rock has never been thoroughly sampled the value of the ore can not be determined. In picked specimens of small size the copper content is 4 or 5 percent, but the strata thus far exposed that carry the malachite average only a fraction of 1 percent copper, which is entirely too low to be of any economic value.

The malachite is irregularly distributed throughout the conglomerate and is not confined to any definite horizon or series of beds—a condition that would be a serious inconvenience in the development of the property. The extent of the copper-bearing rocks is not known as the region is covered with vegetation and hillside wash.

Although there can be no disagreement regarding the value of the deposit thus far exposed, an unfounded belief exists that deeper development would reveal valuable ore. The existence of valuable ore is, however, highly improbable, although the character of the ore would unquestionably change with depth. The malachite would give place to sulphide minerals, either chalcocite or chalcopyrite, but the tenor would not necessarily be changed.

The origin of the copper in the rocks is believed to have been entirely independent of any relation with igneous rocks. The nearest point at which the Triassic diabase comes to the surface is about three miles south of the deposit. The only way in which the diabase could have contributed to the deposition of the copper would have been by the intrusion of other dikes in the vicinity of the deposit which never reached the surface. Hot ascending waters, stimulated by the proximity of the mass of heated rock, could have carried the copper from these dikes into the conglomerates in the form of sulphides, which later changed under atmospheric action into the basic carbonate that is now present.

The deposits have probably originated in the way that so many other copper deposits in red sandstones in different parts of the world are supposed to have been formed. The inclosing rocks were deposited rapidly under arid conditions, following a long period of rock decay, and possibly some copper sulphide minerals from the pre-Cambrian crystalline rocks near by were swept into the same basin. When later percolating waters that contained salt or gypsum in solution passed through these beds the copper was segregated by solution and reprecipitation, probably in the form of chalcocite. The later alteration to malachite has been effected by the action of downward-moving waters charged with oxygen and carbon dioxide.

Manganese

Throughout the region there is abundant evidence of the presence of manganese in the form of dendritic markings of manganese oxide along the joint cracks of decayed rocks, especially in the areas of gneiss. Under such conditions local segregations of manganese oxide should be found. However, as the hydrous oxides of iron and manganese are dissolved and precipitated in the same manner, the manganese oxide, the less abundant of the two, is seldom found distinct

from the iron oxide. Almost all the limonite iron ores of the region contain some manganese, and in some mines the ore averages from 1 to 3 percent of manganese. Such ores have always been in demand for the production of basic iron. In general, the limonite ores of the Cambrian quartzites, which are found along the slopes of the mountains and which are termed "mountain ores," contain the highest percentage of manganese. The manganese-bearing material in most of the ore is a mixture of pyrolusite and psilomelane, although specimens of each separately are sometimes found.

Where the manganese is associated with limonite it can seldom be recognized except by the darker color of the ore. In certain limonite mines layers of ore high enough in their manganese content to be called manganese ores have been found. Several mines in the region have shipped small quantities of this ore, but it was always incidental to the mining of the iron ore. In the Wharton mine of the Thomas Iron Co., about one and one-half miles southeast of Hellertown, the iron ore averaged more than 2 percent of manganese and here and there specimens of nearly pure manganese oxide were found. One of these specimens, which showed beautiful dendritic structure, and which was presented to the museum of Franklin and Marshall College, Lancaster, Pa., by Dr. B. F. Fackenthal, Jr., yielded the following results when analyzed in the laboratory of the Thomas Iron Co.: Fe 0.868, SiO_2 0.46, P 0.046, Mn 52.72.

The manganese content of the limonite ores found in the limestone regions is apt to be lower than in those just described, yet in some mines very small pieces of high-grade manganese ore have been found.

Although manganese is widespread throughout the region in association with the limonite ores there is no probability that any deposit is rich enough in manganese to be developed independently of the iron ores.

Mineral Pigments

For many years the mining and preparation of mineral pigments has been an active industry in this part of Pennsylvania, and at the present time (1938) paint companies are located in Bethlehem and Easton. The bulk of raw materials used comes from other regions, as each plant requires a great variety of materials, such as no one district produces. The paint industry of the region, however, owes its original development to the local occurrence of ocher, umber, and black shales, which have long been mined in limited quantities.

Ocher.—Ocher, which is a mixture of clay and limonite, is almost invariably associated with the limonite iron ores that have been so extensively worked in different parts of the county. During the

active operation of the iron mines the better grades of ocher were frequently taken out separately, washed, and marketed for paint. This was the beginning of the present paint industry of the region. Some years ago paint mills that used local ores almost entirely were operated just west of Pine Top and also near Bingen. The plant of Reichard-Coulston, Inc., first known as the Blue Mountain Paint Mills and later as Henry Erwin & Sons, began operations at the present site along Monocacy Creek just north of Bethlehem in 1868.

In most places no attention was paid to the ocher while the limonite iron mines were in operation, and everything brought to the surface —iron ore, ocher, and different kinds of white, red, and black clays— was put into the log washers. The coarse ore was saved, and the water carrying all the finer materials in suspension was carried through troughs to large ponds made by earthen dams. These ponds for the collection of sediments were necessary in order to avoid the obstruction of the streams into which the waste water flowed. While the iron mines were being worked these deposits of mud were regarded as worthless, but in recent years some of them have been found to contain some fairly good washed ocher. At certain times all the material washed from the ore was highly colored, and these layers when thick enough can be readily separated from the beds that are more sandy or less highly colored with limonite. The sediment deposited near the place where the water entered the pond invariably contains too many coarse particles to be of value for paint, but at the sides of the pond farthest away from the mine, only the finest sediments were deposited, and washed ocher of fine quality can be obtained there in some deposits.

Within the county at the present time no ocher or limonite iron ore is being mined nor is any ocher being obtained from mud-dam deposits. In other counties, however, ocher of both kinds is being worked, the occurrences being similar to those prevailing within the county. It is probable that some of the iron ore deposits which, when formerly worked, yielded considerable marketable ocher, might be found to contain equally as good material as that now obtained in nearby regions. The demand for this material, however, is not great enough to justify the necessary investigations. The amount of mud-dam material that can be marketed is also small, and consequently there is no necessity for examining these deposits, even though this work could be done rather easily by shallow excavations. Many mud-dam deposits are present in the region, for a settling pond was built near almost every limonite mine. A few years ago, C. K. Williams & Co., Easton, reopened one of the old iron mines in the north slope of Morgan Hill and worked it for a short time for ocher.

The following analyses of materials are characteristic of the ochers and mud-dam deposits that have been mined:

Analysis of ochers from Topton, Berks Co. and Easton.

[Furnished by Henry Erwin & Sons]

	1	2	3
SiO_2	55.50	58.50	39.70
Al_2O_3	18.66	20.15	12.36
Fe_2O_3	17.49	15.25	37.64
MgO	.....	.....	1.37
Combined water	8.35	6.10	7.83

1. Best grade of ocher from Topton.
2. Second quality of ocher from Topton.
3. Ocher from mine of A. K. S. Sampson, South Easton.

Analysis of mud-dam deposits 1¼ miles northeast of Breinigsville, Lehigh County[24]

[A. S. McCreath, Analyst]

Silica	60.53
Alumina	17.40
Ferric oxide	9.29
Lime	.08
Magnesia	1.92
Water	5.51
Alkalies (by loss)	5.27

Umber.—Much of the ocher of the region contains small amounts of manganese oxide and almost every analysis of limonite iron ore shows its presence. Under these conditions it seems rather strange that in few localities is the percentage of manganese great enough for the mixture to be called umber.

On the southwest slope of Camels Hump, about two and one-half miles north of Bethlehem, there is a deposit of umber that was formerly worked by Henry Erwin & Sons and later by C. K. Williams & Co. The deposit was worked in a small way for more than twenty-five years. Mining was by shallow open pits and shafts. The following section at one side of the main pit is typical, although a different arrangement of the materials may be found ten feet distant.

Section in umber pit of C. K. Williams & Co. 2½ miles north of Bethlehem, Pa.

	Feet
Soil and hillside wash	3
Reddish-brown clay	1½
Light-yellow ocherous clay	5
Darker-yellow ocherous clay	½
Dark-brown umber (base not exposed)	6
	16

In one place a pit was sunk to the depth of 48 feet, but in most places the umber does not extend that far. White and yellow clay is said to lie beneath the umber bed.

[24] Pennsylvania Second Geol. Survey, Rept. D, p. 33, 1875.

The hillside wash contains many angular pieces of gneiss that have been washed from the small hill of gneiss that lies to the north and that has reached its present position by a strike fault along the north side of the hill. Within the bed of umber there are a few layers and pockets of yellow ocher, some of which are as much as 14 inches thick. The umber bed further contains many small pieces of vein quartz, fragments of iron ore, and limonite geodes filled with drab clay. These impurities are more abundant in the upper portion.

The umber and associated materials represent the decomposition and replacement products of the Hardyston quartzite, which extends along the south flank of the hill, as shown by the float rock. The umber deposit also contains some pieces of the quartzite that have resisted decomposition.

The umber was shipped to Easton, where it was washed and ground. The finished material commanded a price of $18 to $20 a ton.

A short distance east of these workings a shaft was sunk several years ago, and several tons of umber lie near the caved shaft. Though the color is good the large amount of grit is objectionable.

Black shales.—In the vicinity of Nazareth some very black carbonaceous shales were used for many years in the manufacture of black paint. Rogers[25] says:

> In the neighborhood of Nazareth, which is on the line dividing the Slate from the Limestone formation, a material is procured, which answers the ordinary purpose of black paint. This appears to be simply a more than usually carbonaceous, black and soft variety of the slate, occurring near the base of the formation a little above its contact with the Limestone. . . . It requires to be ground in a dry mill, and levigated in troughs by passing over it a stream of water. Thus prepared, it constitutes, when mixed with oil, a very excellent pigment for the exterior of houses, fences and other structures exposed to the weather.

A traveler in that region in 1799 reports the use of the same material, so it would seem that these slates were quarried for paint for many years.

> On our return to Nazareth we saw two men searching for coal. They had penetrated to the depth of twelve feet, and were flushed with sanguine expectations of success.
>
> They were prompted to this search by the opinion of a person who had passed this way not long before and was acquainted with the coal mines of Europe.
>
> The steward had taken from the side of the hill, near this place, a saponaceous black earth, which he had ground and mixed with oil and used as paint. It appears as well and as durable as any other colour. He has by experiments altered the first appearance of black, and made samples of other colours with it.[26]

A little of the refuse slate from the slate quarries has been ground and used for paint.

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[25] Rogers, H. D., Second Annual Report on the Geological Exploration of the State of Pennsylvania, p. 35, 1838.

[26] Ogden, J. C., Excursion into Bethlehem and Nazareth, in Pennsylvania, in the Year 1799, Philadelphia, 1805.

Gold, Silver, Lead, Zinc

From time to time there have been reports of valuable deposits of rare mineral, particularly gold and silver, in the rocks of the region, mainly in the gneiss hills south of the Lehigh River and in Kittatinny (Blue) Mountain. Some of these have been inspired in the not uncommon expressed belief that "them hills were not put there for nothing."

M. S. Henry in his unpublished History of Northampton County mentions one specific illustration.

> Near the base of the mountain at this place (Smith's Gap), a number of Gentlemen some years ago, hearing the "mountain man" at work in the bowels of the Earth, probably also discerning the blue flames issuing from his work shop, these and other unnatural indications induced them to spend considerable sums in mining for the supposed silver ores that were said to be here. But as the "spell" could by no means whatever be taken off, these mines lay unexplored until this day.

Early residents in the vicinity of Little Gap reported the "moan of the mountain" which they likewise interpreted to mean the existence of silver ore.

A geologist will not deny the possibility of traces of silver ore being found in the sandstones and conglomerates of Kittatinny (Blue) Mountain, inasmuch as pockets of lead ore (galena) have been found elsewhere in the State in rocks of this age and also the common association of silver minerals with galena. However, one can say that there is extremely small probability that any occurrence of commercial importance will ever be discovered in this section.

A similar statement may be made concerning gold ore. Pyrite and quartz, such as yield gold in economic quantity in rocks approximately the same age in the southern Appalachians, are not uncommon minerals in the gneisses of Northampton County. Some of these may possibly contain traces of gold, as has been reported, but probably in amounts too small to possess any value. Chance (1882) says that some of the pyrite cubes in the Shawangunk conglomerates at the Delaware Water Gap are auriferous.

The Friedensville zinc ore deposits of the Saucon Valley are within less than a mile of the Northampton County line. Some persons have expected that these ore bodies may extend into this county, although up to the present time there is no indication that they do.

Cement

The most valuable mineral deposit of Northampton County, with the exception of the soils, is the cement rock of the Jacksonburg formation. It extends across the entire county from Belvidere to Northampton, with detached areas near Portland and Brodhead. Large

portland cement plants have been erected at thirteen different places. From this section many millions of barrels of cement have been widely shipped to domestic and foreign markets. The cement district of the county forms a part of the "Lehigh District" which includes the cement plants of Berks, Lehigh, and Northampton counties, Pa. and Warren County, N. J. All of them obtain the bulk of the required stone from quarries in the Jacksonburg formation, although several must bring in some higher-grade limestone from other sections to obtain the proper mix.

As in other regions the manufacture of natural hydraulic cement preceded that of portland cement. In New York the construction of the Erie Canal in 1818-1819 led to the discovery of natural hydraulic cement, and in this region the digging of the canal of the Lehigh Coal & Navigation Co. (1826-1830) accomplished the same result. Rock suitable for hydraulic cement was found just above Lehigh Gap, where Palmerton is now located, and also at Siegfried's Bridge (now Northampton). The rock at Lehigh Gap of Helderberg age seemed to be preferable, and a cement mill was built there under the direction of the company's engineers. This plant was operated by Samuel Glace from 1826 to 1830 and furnished material for many of the canal locks. When the best cement rock near Lehigh Gap was exhausted, material was quarried about six miles east of the gap and hauled to the plant. However, in 1830 it was decided to abandon the mill and to erect a new one at Siegfried's Bridge, where suitable rock was known to be obtainable. In a small pamphlet by William H. Glace, entitled "A Narrative of Hydraulic Cement Mined in the Lehigh Valley," the following description is given:

> Capt. Theodore H. Howell, residing at Siegfrieds, informed me that when he came there in 1837 there were four kilns erected and in operation. They were known as draw kilns, fire being placed in the eye at the bottom of the kilns, drawn at the bottom and hoisted up an incline plane or tramway and emptied into a hopper, where the stones were crushed by machinery shaped like a corn crusher, then dropped down and ground by burr millstones, then placed in boxes or trays with handles, then transported in scows to points on canal where needed. These scows were drawn by mules with a steersman on a platform on the rear of the scow, having a large tiller, fifteen feet long, ending in a large blade or paddle, which tiller was fastened on a socket at the balance point, and thus lifted with little exertion at will, and when in use was a powerful means to turn the boat in any direction wanted. At that time the capacity of this plant was ten barrels per day.
>
> The canal, from this place down to the Allentown dam, was through a farming community, and the loam and clay on the banks of the canal were vulnerable places for the muskrats, which were plentiful. They seemed to be busy constantly and would in a short time make a hole in the embankment, which if not attended to would empty the canal and stop transportation.
>
> The method to remedy this was an alarm given by the bank watchman, the scow or cement boat sent for, which with the mules trotting, a man in front blowing a horn, giving them the right of way, the steersman on his

platform at the rear, meanwhile the workingmen were emptying the trays (which had been covered with a tarpaulin), on the bottom of the boat, mixing it with gravel and sand, dipping up water from the canal and making the concrete. As soon as the leak was reached a small coffer dam was built around it, water emptied and the concrete applied, stamped with wooden stampers in the break, the frame work removed as soon as grouting hardened. In those years Samuel Glace was supervisor of the canal from Slate Dam to Allentown Dam, in addition to the cement work at Siegfrieds until 1841.

Natural cement continued to be manufactured from the Jacksonburg limestone in the vicinity of the present borough of Northampton. M. S. Henry[27] reports the conditions there in 1860.

On the eastern side of the river, directly opposite the village (Whitehall, now Cementon), are the extensive Hydraulic Cement Works of E. Eckert & Co. These works have been in successful operation for a number of years, and the cement (which is mined in the neighborhood) is said to be equal in every respect to the celebrated Rosendale cement.

Until 1872 the manufacture of natural cement at this place was continued on a small scale. That year the original plant was leased by General J. Selfridge and more kilns were constructed and the production increased to 200 barrels per day. The company became the Old Lehigh Cement Co. A new quarry was opened on the Hokendaqua Creek about a mile east of the plant. Market conditions were so poor that for the next five years the plant was idle most of the time.

Another natural-cement plant, called the Allen Cement Co., was built nearby on Hokendauqua Creek in 1872 and opened a quarry close to the mill. Prime[28] described it in 1878.

The works consist of two small draw kilns and two run of stone, having a capacity of about seventy-five barrels daily. The mill is driven by steam power.

The product of their manufactory is a light yellow cement, and is known in the market as the "Allen" or the "Keystone."

Owing to the low price of cement along the coast and stagnation in business these works have done very little during the last three years.

Meanwhile D. O. Saylor, who operated a natural cement plant at Coplay, began experiments for the production of portland cement and in 1872 began its manufacture just across the Lehigh River in Lehigh County, using stone from the same Jacksonburg strata. For some unexplained reason, for several years the idea was held that the stone east of the Lehigh could be used for natural cement but was unsuited for portland cement. It was not until a few years later that the first portland cement plant in Northampton County was built.

Since that time there has been a gradual extension of the cement industry in Northampton County until in 1938 few desirable sites remain unoccupied. For many years the total production increased

[27] M. S. Henry, History of the Lehigh Valley, p. 302, 1860.
[28] Prime, Jr., F., Pennsylvania Second Geol. Survey, vol. DD, p. 67, 1878.

each year and the building of new plants and the enlargement of old ones just about kept pace with the increasing demand. For a time the competition with other districts was negligible as other regions not favored with argillaceous limestones were slow to appreciate that a good quality of cement could be produced by the combination of calcareous and argillaceous rocks. Though no other cement region occupies so favorable position with reference to accessibility to good cement rock and fuel and proximity to the greatest industrial centers of the country, yet on account of freight charges the market for the product of the Lehigh District has narrowed greatly during the last twenty years. Even foreign cements have been shipped into the Atlantic coast ports. The business slump that began in 1929 and that has brought general stagnation to the building industry has been hard on the cement companies of the region. Some of the plants have been idle most of the time.

This region still possesses advantages over most other cement districts in that the raw stone is composed of the necessary constituents for the production of the best grade of cement. Likewise, in some quarries they are combined in the proper proportions. A few companies are compelled to purchase considerable high-quality limestone from operators in the Lebanon Valley. As yet no plant in the county has attempted to improve the quality of the quarry stone by flotation beneficiation although the feasibility of this process seems to have been proved by an elaborate series of experimental tests undertaken during the past year.

QUARRY METHODS

The quarry methods used by the cement companies are similar throughout the district. If possible the quarry is opened in the side of a hill and the tracks run into the quarry on the level so that as the quarry is extended a greater height of quarry face is obtained. In some places, however, it is necessary to open a quarry by excavating in a fairly level surface, and then the rock must be hauled up an incline to the surface.

In almost every quarry the variations in the rock in different parts make it advisable to have an extensive face and tracks radiating to different points in order to obtain a mixture of uniform composition by combining the rock high in lime with that low in lime.

Formerly the rock was quarried in benches by the use of small drills and small blasts. Now, however, the companies have found it more economical to blow down enormous masses of rock at one time, at some blasts more than 60,000 tons. To do this a series of churn drill holes is put down about ten to fifteen feet back from the quarry face and about the same distance apart and driven to the level of the

bottom of the quarry, which is usually about 100 feet. These holes are then charged with dynamite and exploded simultaneously, an electric detonator being used. The rock is so easily shattered that these great blasts break most of the rock sufficiently to be loaded into cars. The larger blocks are broken by small charges of dynamite placed in holes made by small compressed-air hand drills.

Steam shovels are used for loading the rock into cars. In the quarries that are driven into the hillsides on the level, small locomotives or mules are used to haul the cars to the mill. Where the quarry is sunk below the level of the mill the cars are pushed by hand or hauled by mules to the foot of the incline, where they are attached to a cable to be hauled up the slope. One company uses trucks to transport the stone from the quarry to the mill. The rock is dumped into a storage bin or directly into the gyratory crushers.

PORTLAND CEMENT MANUFACTURE

In general there is little variation in the methods employed throughout the region for the manufacture of portland cement, although somewhat different types of machinery are used. The different stages in a dry-process plant include (1) coarse grinding, (2) drying, (3) fine grinding, (4) calcining, (5) cooling or seasoning, (6) mixing with gypsum and grinding the clinker, and (7) seasoning in storage houses preparatory to bagging or packing in barrels. These processes have been described in many publications that deal with the technical side of cement manufacture.

The first kilns used in the district were upright. They consisted of three compartments, an upper heating chamber, a middle clinkering chamber, and a lower cooling chamber. The pulverized rock was mixed with water and molded into bricks, which were first dried and then carefully placed in the upper chamber by hand. The material passed in turn through the other chambers and was withdrawn at the base. These kilns were not satisfactory, for much of the material was not uniformly burned, the amount of labor required was excessive, and scarcely more than 100 barrels of cement could be burned in each kiln daily. On the other hand, the fuel consumption in the upright kilns, which ranged from 45 to 65 pounds of coal to the barrel of cement, was much less than that required in the rotary kilns.

From the mills the cement is taken to the storage bins, where it remains for some time to season and is then withdrawn for shipment. It is shipped in paper or cloth bags that hold 95 pounds. Originally much was shipped in barrels that held 380 pounds. The Bates valve bag is widely used in the district. One company ships the finished cement in bulk in tight covered freight cars.

The three newest plants in the county, the Sandts Eddy plant of the Lehigh Portland Cement Co., the Keystone and National plants, use the wet process of cement manufacture. This eliminates the drying of the stone but calls for the erection of slurry tanks where the pulverized product is stored. The slurry is agitated by compressed air to prevent the deposition of the rock particles at the base of the tanks. It is pumped from the pulverizers to the tanks and in turn to the kilns.

DIFFERENT KINDS OF PORTLAND CEMENT

At one time the term portland cement had a different significance than now. There was only one kind and only one set of specifications to meet, but within the past few years there have been many changes, and practically every company operating in the district is making several different kinds, each of which is adapted for some particular use or uses. These require different composition in the raw mix; grinding to a definite size, which is generally finer than formerly; and particular kind of burning. These demands have already affected adversely some of the companies of the district that have difficulty in obtaining the necessary ingredients from their properties. This is especially the case when the requirement is for higher lime content in the mix.

So rapidly have these changes come about that it is difficult for one to keep informed concerning them. One cement chemist made the remark a few days ago that his company was now experimenting with fourteen different kinds of raw mixtures. It is beyond the scope of this volume to describe these new types of portland cement. Some require white clay, others bauxite, iron ore, quartz sand and other minerals. Practically all of these call for importations from other regions.

CEMENT ROCK

The description of the Jacksonburg limestone by Ralph L. Miller in a previous chapter contains most of the material necessary for an understanding of the economic phases of the cement rock.

DESCRIPTION OF INDIVIDUAL PLANTS

Lawrence Portland Cement Company.—The plant of the Lawrence Portland Cement Co. is located along the Lehigh River just north of Northampton, apparently at the place where the first natural cement in the county was manufactured in 1830. The company, which began operations in New York State, was reorganized in 1898 and built its plant at its present site. It has been in continuous operation since 1899.

For many years the stone was obtained from a long, narrow and

deep quarry between the canal and the Lehigh Valley R. R. This was finally abandoned and the property of the defunct Bonneville Cement Co. along Hockendauqua Creek was purchased. The quarry is about half a mile east of the plant.

The quarry is the deepest one in the district, with a depth of 385 feet. As the quarry face has been advanced eastward the creek has twice been moved, and it is proposed to move it still farther to the east as the quarry is enlarged.

The stone from the quarry is deficient in carbonate so that it is necessary to add high-grade limestone from the Lebanon Valley. At one time a quarry in the Beekmantown limestone in the north part of Catasauqua was operated to supply this additional stone. Inasmuch as the quarry contained interbedded dolomite layers the stone had to be loaded by hand. The dolomite was sold for flux.

This company besides portland cement has long produced Hy-Test Mason Cement consisting of portland cement clinker and natural cement.

The plant has thirteen kilns of different length and diameter.

Universal Atlas Cement Company.—The Keystone Cement Co., which was the original company, started operations in 1889 on the west side of the Lehigh River between Coplay and Cementon. The name was changed later to the Atlas Portland Cement Co. and a few years ago to its present name when the company was purchased by the U. S. Steel Co. Its plant has long been the largest in the district.

The company began operations on the west side of the Lehigh River in 1890. In 1895 it purchased property at its present site at Northampton and erected Mill No. 2.

The company at different times has operated several quarries in proximity to the mills and one near Howertown, but the one now being worked lies north of the State highway to Bath. It covers 80 acres and has a 160-foot face at the highest place. The rock is fairly regular, although crumpled in places, and dips to the north at angles of 20° to 25°. Throughout the cement rock there are occasional lenses of coarsely crystalline high-grade gray limestone from a few inches in thickness up to four feet, containing over 90 percent $CaCO_3$. This rock when weathered is seen to be composed of fossils, with crinoid stems particularly abundant. Calcite and quartz vein matter is not abundant in the quarry. Because stone as quarried is deficient in carbonates, high-grade limestone is imported from Pine Island, N. Y.

The company has built three different mills at this place and one earlier on the west side of the Lehigh River. Only the latest one,

No. 4 is now in operation. It is equipped with 25 kilns of different sizes, of which 21 are used for ordinary portland cement and the other 4 for white cement. The daily capacity is 12,500 barrels of ordinary cement and 1,600 barrels of white cement.

Lumnite cement, a quick-setting product made with imported bauxite, was made here for a few years but now is being manufactured at Buffington, Ind. White clay from Kunkletown is used for the production of white cement.

To show the variations in the $CaCO_3$ content of the stone, the results of two prospect drill holes put down in the floor of the present quarry are given. The holes are in the west part of the quarry and about 300 feet apart in a north-south direction, at approximately right angles to the strike of the strata.

Prospect drill holes in quarry of Universal Atlas Cement Co.

Depth in feet	Percentage of $CaCO_3$ Hole A	Percentage of $CaCO_3$ Hole B	Depth in feet	Percentage of $CaCO_3$ Hole A	Percentage of $CaCO_3$ Hole B
0-5	78.11	69.18	105-110	75.99	69.60
5-10	76.92	70.18	110-115	74.48	68.34
10-15	74.73	75.21	115-120	71.78	67.67
15-20	80.37	72.45	120-125	72.12	69.77
20-25	75.91	70.94	125-130	76.33	69.94
25-30	76.25	70.68	130-135	77.51	73.03
30-35	78.02	68.92	135-140	81.22	70.85
35-40	73.30	69.01	140-145	75.49	70.35
40-45	78.36	70.85	145-150	75.99	70.68
45-50	76.75	69.43	150-155	74.40	70.35
50-55	74.05	74.29	155-160	73.71	68.51
55-60	79.53	68.84	160-165	77.00	70.85
60-65	74.90	71.94	165-170	79.70	72.69
65-70	71.20	74.54	170-175	74.32	73.12
70-75	73.71	80.75	175.180	75.06	70.35
75-80	76.92	77.65	180-185	78.36	75.47
80-85	74.65	75.13	185-190	77.08	76.22
85-90	75.57	76.97	190-195	79.53	74.63
90-95	75.40	74.63	195-200	79.40	72.87
95-100	77.76	76.22			
100-105	73.04	73.53	Average	75.91	72.16

These analyses show slightly higher $CaCO_3$ than the average run of rock in the quarry. They show very well the change in composition of the rock from bed to bed.

Lehigh Portland Cement Company, Bath Plant.—This plant, located about a mile and a half southwest of Bath, was built in 1904 by the Bath Portland Cement Co. It began production in 1905 and continued to operate until some time during 1930. It has been idle ever since and the mills and other buildings are being dismantled.

For a time two quarries were operated. The larger one a short distance northwest of the mill is within the cement-rock belt. The

stone was greatly crumpled and the amount of calcite and quartz vein matter was excessive. The stone from this main quarry was considerably below a "mix" in $CaCO_3$. The strata have an average dip of about 20° northwest.

The smaller quarry, a short distance southeast of the mill, lies within the cement-limestone belt but the stone is much poorer than that occurring in this belt in the Nazareth region.

Keystone Portland Cement Company.—The Keystone plant is about half a mile southwest of Bath. It is a wet process plant and next to the newest in the county. It began operation in 1928. The quarry contains some high-grade cement limestone in the southern part and argillaceous limestones lower in $CaCO_3$ in the north part. Clay pockets are fairly abundant and troublesome where the best stone occurs, a condition that is noticeable in many other quarries. The strata dip fairly steeply to the northwest. The Martinsburg shale lies only a short distance to the northwest. The contact between the two is sharply marked by a change of slope, much steeper in the slate than in the Jacksonburg limestone. This feature is observable in other regions.

The mill is equipped with four 250-foot kilns. The annual capacity is 2,500,000 barrels.

Pennsylvania-Dixie Cement Corporation. Plant No. 6.—This operation, started in 1900 by the Pennsylvania Cement Co., is located about half a mile east of Bath. For many years it used stone from the quarry adjoining the mill on the west but in recent years has obtained all the required stone from the quarry of Plant No. 4 (formerly the Dexter) by aerial tram.

In the south part of the quarry there is some fairly high-grade limestone of the cement-limestone member of the Jacksonburg but the main part of the quarry is opened in stone of the cement-rock type. The beds dip NW. 15° to 35°. For a time a mixture of the two kinds of stone yielded the proper material for portland cement. Some beds of high-magnesian stone had to be discarded. Another difficulty was the presence of numerous deep solution holes filled with dense, yellow, residual clay. The overburden was also heavy. For these reasons it seemed better to abandon the quarry and bring in the necessary stone from the quarry of Plant No. 4, about 2½ miles to the east.

Unfortunately, the mill and other buildings are located on what appears to be the best stone on the entire property.

Pennsylvania-Dixie Cement Corporation. Plant No. 5.—This plant was erected by the Penn Allen Portland Cement Co. in 1902 and began operation in 1903. It continued to operate until 1929, since which

time it has had no production. The quarry was opened in the north portion of the cement-rock belt, close to the contact with the overlying Martinsburg shale. In general the $CaCO_3$ content of the Jacksonburg decreases from the base to the top and almost uniformly the uppermost beds are markedly deficient. As this was true in the quarry of this company, considerable high-grade limestone had to be purchased from other sources. For a time some low-magnesian stone was obtained from the quarry of the Industrial Limestone Co. near Hanoverville, where the Beekmantown limestone contains this type of stone interbedded with high-magnesian stone. At another time some high-lime stone was obtained from a quarry in the Franklin formation, on the west side of Monocacy Creek near Pine Top.

After the Pennsylvania-Dixie Cement Corporation was formed by the consolidation of various plants, an aerial tram line was constructed to bring stone from the quarry of Plant No. 4 (formerly the Dexter). This tram line was later extended to Plant No. 6.

The mill has eight rotary kilns.

Pennsylvania-Dixie Cement Corporation, Plant No. 4.—This was built in 1899 by the Dexter Portland Cement Co. Production began in 1900 and has continued ever since. This company formerly had two quarries, a small one southeast of the mill in the cement-limestone belt and a larger one to the north in the cement-rock band. For some years the entire supply of stone for Plants No. 4 and No. 6 as well as No. 5 when it was being operated, has come from the main quarry. The quarry was advanced northward and stone lower in $CaCO_3$ obtained. At the present time (July 1938) an extensive stripping operation is uncovering a considerable area of stone in the cement-limestone belt south and southwest of the present quarry. The overburden is heavy and the clay pockets are numerous and deep. The stone in this area should materially increase the $CaCO_3$ content of the quarried rock.

At this plant a high-iron cement is being made by the use of a highly ferruginous clay obtained from the mud-dam deposit of the old Henry Goetz limonite mine about 1¼ miles southwest of Hanoverville.

The present mill is equipped with eight rotary kilns.

Lone Star Cement Corporation.—The plant of the Lone Star Cement Corporation is on the southwest edge of Nazareth. It was built and operated by the Phoenix Portland Cement Co. from 1900 until its acquisition by the present company a few years ago. The original quarry was northwest of the mill in the cement-rock belt but the present quarry east of the buildings exposes the cement-limestone in the

southern half of the quarry and the cement rock in the northern part. The general dip of the strata is about 25° NW. with a strike of N. 10° E.

Nowhere else in the entire county is there such a good illustration of the relationship of these two members of the Jacksonburg. A clay pocket is developed at the contact of the two. The lower member appears much more massive than the upper one. A series of drill holes shows well the chemical composition of the stone in different parts of the quarry.

Analysis of drill hole samples in quarry of Lone Star Cement Corporation

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	7.00	7.62	8.24	9.20	10.68	10.40	9.88	14.20	13.52	13.52	13.96
$Al_2O_3+Fe_2O_3$	2.80	2.32	2.28	4.36	5.16	5.00	4.72	7.00	7.04	6.60	6.76
$CaCO_3$	85.25	84.09	83.55	81.28	78.18	79.25	80.15	73.20	74.00	74.70	73.38
$MgCO_3$	5.12	6.06	5.64	5.12	5.00	4.70	4.67	4.36	4.36	4.27	4.55
Ratio of SiO_2 to $Al_2O_3+Fe_2O_3$	2.50	3.28	3.61	2.11	2.07	2.08	2.08	2.03	1.91	2.05	2.07

Holes 1, 2, 3 and 4 are 82 feet deep; are located along south side of quarry, are approximately parallel to the strike, and are confined to the strata of the cement-limestone member.

Holes 5, 6 and 7 are 72 feet deep; are located along south portion of east wall, are approximately at right angles to the strike, and are confined to the cement-limestone member.

Holes 8, 9, 10 and 11 are 122 feet deep; are located along the north wall of the quarry, are approximately parallel to the strike, and are confined to the lower beds of the cement-rock member of the Jacksonburg.

It can readily be seen that the quarry yields stone for a mix with no necessity for importing limestone. As the quarry face is advanced northward and higher strata in the cement-rock member are encountered it is reasonably certain that the $CaCO_3$ percentage will be lowered.

About thirty years ago some natural cement was made at this plant and a small quarry about half a mile to the north was opened in the upper beds of the formation, close to the Martinsburg shale contact, to obtain some stone low in $CaCO_3$. Two analyses of the stone are given.

Analysis of upper beds of Jacksonburg formation

	Northeast face	Northwest face
SiO_2	29.68	29.04
Al_2O_3	6.63	6.92
Fe_2O_3	2.23	2.84
$CaCO_3$	54.62	51.97
$MgCO_3$	4.18	6.15

The plant is equipped with six rotary kilns of various sizes.

Nazareth Cement Company.—The Nazareth Cement Co. plant, located in the southeast part of Nazareth, was built in 1906-1907 and had its first production in 1907. The quarry is large and contains high-grade stone. Strata of the cement-limestone member are worked in the southern part of the quarry and the lower beds of the cement-rock member in the central and northern parts. The contact between the two members is marked by more massive limestone beds below and thin-bedded argillaceous strata above. The lowest (oldest) strata worked in the quarry dip about 42° NE. The dip decreases to the north and the beds are nearly flat in places. The depth to the underlying Beekmantown decreases eastward. The structure is somewhat spoon-shaped, with successively lower strata coming to the surface south and east. The analogy is less appropriate in the west and northwest parts.

There are numerous small lenses of high-grade crystalline gray limestone in the upper cement-rock. Quartz and calcite veins are not abundant although distinctly noticeable in places.

The $CaCO_3$ content of the stone in the quarry is so high that the clay of the surficial stripping is saved so that some can be added when the lime is too high for the mix. This is in striking contrast with other plants in the region where the continual problem is to get stone sufficiently high in $CaCO_3$ to avoid the purchase of high-grade limestone.

The plant is equipped with eight kilns of various diameters and lengths. The annual capacity is 2,500,000 barrels.

Hercules Cement Corporation.—The plant of the Hercules Cement Corporation is south of the Nazareth-Stockertown road a short distance west of Stockertown.

The quarry is mainly in the lower portion of the Jacksonburg formation and the stone quarried is sufficiently high in $CaCO_3$ to obviate the necessity of bringing in any stone from outside. The stone varies considerably in composition in different parts of the quarry. The dolomitic limestones of the Beekmantown formation appear in the south wall. Several thin beds of bentonite (altered volcanic ash) are exposed in the quarry. The quarry face is 105 feet high at the highest place. Trucks have been used to haul the stone from the quarry to the mill.

This plant was erected in 1907 by the Atlantic Portland Cement Co. Lack of capital prevented it from being put in operation. In 1916 it was purchased by the present company and production started in 1917.

The mill is equipped with ten kilns. The annual capacity is 2,200,000 barrels.

Lehigh Portland Cement Company, Sandt's Eddy Plant.—This plant was the first wet process plant in the Lehigh District. The plant was built by the Quaker Portland Cement Co. in 1911. It began production in 1926. The first quarry was opened northeast of the mill but as the stone was not desirable a new quarry was opened half a mile northwest of the mill. It was started in a hillside and the face has increased in height as the quarry has been extended. At one place the face is 135 feet high. A 50-foot excavation has now been made in the floor of the quarry. The quarry face is about 680 feet long.

The stone varies considerably in composition in various parts of the quarry. Stone too low in $CaCO_3$ to be used economically occurs between good stone in the same beds. Evidently differential solution has removed considerable of the carbonate. This poor stone, which stands about midway of the quarry, is called "the monument." The quarry furnishes stone suitable for the mix and no imported stone is required.

The structure of the strata is fairly simple. It is a broad syncline with the south limb fairly steep. Along this south wall an overthrust fault has brought twenty feet of dolomitic Beekmantown limestone over the Jacksonburg. The dolomite is badly shattered and contains numerous quartz and calcite veins.

Clay pockets are not numerous but some of them are fairly deep. They seem to occur in places where the rock has been shattered and faulted. No large fault displacements are known in the cement rock but there are numerous minor faults.

A small new quarry opened north of the mill is yielding some stone with 80 to 82 percent $CaCO_3$.

Alpha Portland Cement Corporation.—This company has operated its Martins Creek plant since 1904. The quarry is very close to the bank of the Delaware River at Martins Creek. It was opened in the side of a steep hill and has been developed northward until a face height of 210 feet has been reached at the north side. A further sinking is being started that will increase the depth of the quarry 60 feet or more.

An anticline approximately parallel with the course of the Delaware River extends through the quarry. The strata on the southeast side dip very gently to the southeast whereas on the northwest side, in which the main portion of the quarry has been developed, the strata dip northwest 25° to 35°.

The underlying Beekmantown dolomite should outcrop in the river bed only a short distance southeast of the quarry and has been encountered in some of the drilling in the south portion of the quarry.

At one point in the south wall the underlying Beekmantown dolomite has been faulted upwards and extends about fifteen feet above the floor of the quarry.

The two divisions of the Jacksonburg are represented in the quarry. The cement limestone is exposed in the southeast part of the quarry and consists of the usual coarsely crystalline gray to black limestone. An unusual feature is the somewhat gnarly character of the limestone and its development into lenses separated by thin beds of calcareous shale that bend about them. Although the limestone itself contains over 90 percent $CaCO_3$, the presence of these thin interbedded shales reduces the average composition considerably.

The cement limestone extends across the quarry and the new 60-foot level to be developed will yield this type of stone over a considerable extent of the quarry. The cement limestone dipping to the northwest disappears beneath the cement-rock member of the Jacksonburg, which is considerably lower in $CaCO_3$. Much of it contains only about 71 percent $CaCO_3$.

It would be possible to work the quarry in such a way as to obtain a mix but in view of the fact that the cement limestone is limited in quantity, a plan has been adopted to push the face back regularly, even though it necessitates using a great amount of stone below the mix, and requires the addition of high-grade limestone that is brought from Annville, Pa. The amount of limestone added varies but runs in the neighborhood of 10 percent.

Although the quarry floor in 1938 is about twelve feet below the level of the water in the Delaware River nearby, there seems to be practically no seepage from the river. The water pumped, which is not great, appears to be ground water, probably coming from the hills to the north. The stone in the quarry seems to be almost everywhere very tight. There is comparatively little crumpling, and calcite and quartz vein matter is much less abundant than in most of the cement quarries of the county.

There are two mills on the property but only one is now in operation. It contains nine rotary kilns of different dimensions.

National Portland Cement Company.—The newest cement plant in the county, built by the National Portland Cement Co., began operations in 1935. It is about midway between Bethlehem and Nazareth along Monocacy Creek.

The quarry is in a down-faulted (possibly some down-folding as well) block of Jacksonburg limestone in an area of Beekmantown limestone. The known area of Jacksonburg is limited, as shown on the map. Some of the bounding lines at the present time are somewhat indefinite because outcrops are rare.

So far as the prospecting has gone, it has developed a large tonnage of the cement-rock phase of the Jacksonburg and a smaller amount of the cement limestone. By working the quarry carefully a mix can readily be obtained.

The chief difficulty encountered is the quantity of water that enters the quarry and necessitates pumping up to 8,000 gallons per minute. The water comes partly from the normal underground circulation and partly from Monocacy Creek. Faulting in the area has facilitated easy passage of water through the shattered and cavernous limestones.

The plant uses the wet process. It is equipped with two kilns, 10 feet in diameter and 372 feet long. The annual capacity is 1,500,000 barrels.

Northampton Portland Cement Company.—A cement plant under the name of the Northampton Portland Cement Co. was built and operated in southeast Stockertown for a few years but has long been abandoned and the buildings torn down. In 1909 it had a production of 404,487 barrels, and the following three years 132,191, 104,031 and 68,321 barrels. The last production seems to have been in 1912. Financial difficulties probably brought about the discontinuance. The buildings for a time were used by the Atlantic Potash Company in their endeavors to extract potash from New Jersey glauconitic greensand.

Bonneville Portland Cement Company.—This company operated a cement plant along Hokendauqua Creek east of Siegfried (north end of Northampton) prior to 1907. Production figures are not available. The property was purchased by the Lawrence Portland Cement Co. and the greatly enlarged quarry now supplies the stone for that company.

Lily White Cement Company.—About 1903 a property was purchased along the Lehigh & New England R. R. northeast of Hanoverville and a company was organized under the name of the Lily White Cement Co. to produce portland cement. The stone that it was proposed to use belongs to the Beekmantown. The preliminary superficial examination revealed some layers of low-magnesian stone, suitable for cement manufacture. When a more careful investigation was made, it was found that a great deal of dolomite was interbedded with the good limestone, and the folding so intricate that it was difficult to separate the two. The construction of the mill buildings had been started.

The property passed into the possession of one of the local banks and was operated for several years by the Industrial Limestone Company.

Production of Portland Cement in Northampton County, by Companies

Year	Universal Atlas	Alpha	Hercules	Keystone	Lawrence	Lehigh: Bath	Lehigh: Sandts Eddy	Lone Star (Phoenix)	National	Nazareth	Northampton	Penn-Dixie: No. 4 (Dexter)	Penn-Dixie: No. 5 (Penn Allen)	Penn-Dixie: No. 6 (Pennsylvania)
1896........	x													
1897........	x													
1898........	x				R									
1899........	x				x			O				O		
1900........	x				x			x[a]				x[a]		O
1901........	x				x			x[a]				x		x[a]
1902........	x				x			x				x	O	x[a]
1903........	x				x			x				x	x[a]	x[a]
1904........	x	x			x	O		x				x	x[a]	x[a]
1905........	x	x			x	x[a]		x				x	x[a]	x
1906........	x	x			x	x[a]		x		O		x	x[a]	x
1907........	x	x			x	x[a]		x		x[a]		x	x	x
1908........	x	x			x	x[a]		x		x		x	x	x
1909........	x	x			x	x		x		x	x	x	x	x
1910........	x	x			x	x		x		x	x	x	x	x
1911........	x	x			x	x		x		x	x	x	x	x
1912........	x	x			x	x		x		x	x	x	x	x
1913........	x	x			x	x		x		x	D	x	x	x
1914........	x	x			x	x		x		x		x	x	x
1915........	x	x			x	x		x		x		x	x	x
1916........	x	x	O		x	x		x		x		x	x	x
1917........	x	x	x[a]		x	x		x		x		x	x	x
1918........	x	x	x		x	x		x		x		x	x	x
1919........	x	x	x		x	x		x		x		x	x	x
1920........	x	x	x		x	x		x		x		x	x	x
1921........	x	x	x		x	x		x		x		x	x	x
1922........	x	x	x		x	x		x		x		x	x	x
1923........	x	x	x		x	x		x		x		x	x	x
1924........	x	x	x		x	x		x		x		x	x	x
1925........	x	x	x		x	x		x		x		x	x	x
1926........	x	x	x		x	x	x	x		x		x	x	x
1927........	x	x	x	O	x	x	x	x		x		x	x	x
1928........	x	x	x	x	x	x	x	x		x		x	x	x
1929........	x	x	x	x	x	x	x	x		x		x	x	x
1930........	x	x	x	x	x	x	x	x		x		x	x	x
1931........	x	x	x	x	x	D	x	x		x		x	x	x
1932........	x	x	x	x	x		x	x		x		x	x	x
1933........	x	x	x	x	x		x	x		x		x	x	x
1934........	x	x	x	x	x		x	x		x		x	x	x
1935........	x	x	x	x	x		x	x	x	x		x	x	x
1936........	x	x	x	x	x		x	x	x	x		x	x	x
1937........	x	x	x	x	x		x	x	x	x		x	x	x

x—Production during year.
a—Figures not available.
O—Organized
R—Reorganized.
D—Production discontinued.

Production of Portland Cement in Northampton County, in Barrels

Year	Barrels	Price Per Barrel	Total Value
1896	106,486		
1897	365,474		
1898	867,243		
1899	1,137,023	*$1.43	$1,626,942.89
1900	2,208,438+	*1.09	2,407,197.42+
1901	3,405,401+	*.99	3,371,346.99+
1902	4,192,512+	*1.21	5,072,939.52+
1903	4,159,095+	*1.24	5,157,277.80+
1904	5,117,460+	*.88	4,503,364.80+
1905	6,765,077+	*.96	6,494,473.92+
1906	4,167,201+	*1.13	4,708,937.13+
1907	11,597,263+	*1.11	12,872,961.93+
1908	10,071,114+	.75	7,553,335.50+
1909	12,402,399	.69½	7,619,667.31
1910	14,841,202	.72	10,685,665.44
1911	14,245,647	.72	10,256,865.84
1912	13,779,028	.67	9,231,948.76
1913	13,211,761	.84	11,097,879.24
1914	12,346,991	.81	10,001,062.71
1915	14,399,478	.70	10,079,634.60
1916	13,584,352	.94	12,769,290.88
1917	13,969,644+	1.22	17,042,965.68+
1918	11,308,377	1.52	17,188,733.04
1919	13,191.944	1.64	21,634,788.16
1920	15,014,198	1.93	28,977,402.14
1921	13,442,793	1.78	23,828,158.54
1922	15,882,696	1,63	25,888,794.48
1923	18,375,198	1.81	34,259,108.38
1924	20,278,321	1.72	34,878,712.12
1925	20,830,037	1.74	36,244,264.38
1926	22,307,922	1.71	38,146,546.62
1927	23,753,973	1.55	36,818,658.15
1928	21,587,680	1.52	32,813,273.60
1929	20,503,836	1.41	28,910,408.76
1930	20,495,968	1.39	28,489,395.52
1931	15,316,807	1.09	16,495,319.63
1932	8,714,488	.99	8,632,343.12
1933	6,950,344	1.27	8,826,936.88
1934	8,426,863	1.50	12,640,294.50
1935	9,011,543	1.46	13,156,852.78
1936	12,837,148	1.38	17,715,264.24
1937	12,330,143	1.51	18,618,515.93
Total	534,696,568+		$636,717,529.33+

* Average price per barrel in country, other prices per barrel are value in Lehigh District.

Limestones

The limestones of Northampton County, exclusive of the argillaceous variety described under cement, are widespread and have been quarried in scores of places. It is only a slight exaggeration to say that a quarry has been opened on every farm in the limestone areas. The different limestone formations—Tomstown, Allentown, Beekmantown, Jacksonburg (cement limestone) and Martinsburg—have been described in earlier chapters. In this place their utilization will be discussed.

The limestones of the county have been used for building purposes (described under Building Stones), for the manufacture of lime, for flux and for crushed stone. The earliest use was for building stone and for lime. The first settlers opened small quarries where they got stone for their own use to burn lime for mortar or for fertilizing the soil. Those farmers without limestone on their own property sometimes hauled the stone from their neighbors' farms and burned it in small kilns near their residences.

When the iron mines were opened in the region and furnaces erected there was a demand for fluxing stone, and several quarries of considerable size were operated for this purpose. With the advent of portland cement and the construction of concrete roads, bridges and buildings, the demand for crushed stone for aggregate developed. Each of these uses has followed more or less in the order named and at the present time crushed stone is the most important. Some quarries have at different times been worked for each of the uses mentioned but seldom for more than one at the same time.

Limestones for lime.—More limestone quarries in Northampton County have been opened to get stone for burning than for any other purpose. Most of them are small and are now filled with rubbish and the kilns nearby are in ruins. Almost every clump of trees in the fields conceals one of these abandoned quarries. Of course, many of the quarries were opened along the stream bluffs. It was the common practice for the farmers to quarry and burn the stone during seasons when there was little work to be done in the fields. The kilns were constructed of field stones, many of glacial origin, and wood was used for fuel. The burning was not very efficient and the limed fields now contain pieces of chalky-white, partially-burned stone that may have lain there for many decades. Students have been puzzled by these limestone fragments, so unlike the other limestones in appearance. The farmers felt that it was profitable to add lime to the soil every three to five years and by a definite program one-third to one-fifth of the farm would be limed each year.

Although the great bulk of the lime produced was used for the improvement of the soils, at all periods the lime needed to supply the local demand for mortar also came from these same plants.

Gradually the belief in the necessity of liming soils waned as fuel became scarcer and labor more expensive, and the farmers ceased to manufacture their own lime. In a few well-favored places larger kilns were erected, coal was shipped in for fuel, and larger production resulted. The product was sold for several miles about and even shipped considerable distances. As it came into competition with lime produced in other sections, more care was taken in its manufacture, both in the selection of the stone and in the burning.

The early product naturally was of variable quality. The farmer burned whatever stone he had on his property. Some of the Tomstown limestones were high in silica and alumina and almost all others were highly magnesian.

Portland.—The lime industry has been carried on in the vicinity of Portland more extensively than in any other place in Northampton County. Operations started there as early as 1830. Several openings have been made and kilns have been erected. Allentown, Beekmantown and Jacksonburg limestones have been quarried. The largest quarry belongs to the Keller Estate. Located at the south end of the borough it is about 300 by 500 feet in size, with a working face at the highest point of about 85 feet. The upper beds belong to the Beekmantown formation, and the lower to the Allentown. The Allentown strata are considerably harder. All the limestones north of Jacoby Creek also belong to the Allentown.

All the limestones of the large quarry are highly magnesian. The three analyses given may be regarded as typical. The first two represent samples from strata on the north and east sides and the third is a composite sample composed of fragments picked up near the kilns. All of these analyses were made by J. H. Heintzelman.

Analysis of limestone from Keller quarry, Portland

	1	2	3
SiO_2	8.88	4.76	7.24
$Al_2O_3+Fe_2O_3$	1.72	1.64	2.04
$CaCO_3$	49.22	51.37	59.07
$MgCO_3$	40.38	43.17	31.82

South of the Keller quarry on the Miller Estate, there are several openings in the Beekmantown limestones where low- and high-magnesian strata are interbedded. The dolomitic stone predominates. Here some of the low magnesian rock was sorted out for the production of high-calcium lime for mortar and for soil use by those farmers

who wanted that kind of lime. Some of the Beekmantown limestone here shows the blotched conglomeratic phase so prominently developed in the Beekmantown in other parts of the State. Analyses by J. H. Heintzelman show the different types of rock.

Analysis of Beekmantown limestones from quarries on the Miller Estate, Portland

SiO_2	4.00	6.24	4.40	2.36	7.24	5.20
$Al_2O_3+Fe_2O_3$ ..	1.04	1.64	1.08	2.08	2.04	1.48
$CaCO_3$	53.16	51.37	53.25	54.23	59.07	88.60
$MgCO_3$	43.57	41.84	42.27	43.08	31.82	4.58

About three-fourths mile south of Portland and close to the contact with the Martinsburg shales, one quarry has been opened in the Jacksonburg limestone. The rock is dark colored, thin-bedded and relatively very soft. Some slabs in this quarry contain abundant branching bryozoa and crinoid stems. There is only a limited amount of this type. An analysis of this rock was made by J. H. Heintzelman: SiO_2 2.80, $Al_2O_3+Fe_2O_3$ 1.20, $CaCO_3$ 93.43, $MgCO_3$ 2.82.

The structures of the strata in the Portland region are fairly regular. In some openings the strata are almost horizontal but in general they dip to the southeast at angles of twenty degrees to forty degrees. Several faults with a general east-west trend break the rock into blocks. A fault has cut off a small block of the Jacksonburg, dropped it down, and brought the Beekmantown in contact with the Martinsburg.

A fault is the source of a large fine spring close to the highway at the intersection of Delaware and State streets. The water from this spring has long been prized by some of the residents. When the large quarry was worked, the pumps usually had to be operated about eight hours a day pumping about 500 gallons per minute. The course of a small stream was changed at one time to decrease the amount of water entering the quarry from the surface.

For many years the lime operators in the Portland region shipped large quantities of lime into the anthracite region where it had an excellent reputation. Attempts have recently been made to reestablish the industry to supply that market. Some of the kilns, all of the upright type, are said to be in good condition.

Hanoverville.—Another important lime plant in Northampton County was located just south of Monocacy Creek northeast of Hanoverville. At this place, about the beginning of this century, some high-grade low-magnesian limestone was prospected and a company organized to make portland cement. The management adopted the name, The Lily White Cement Company. Foundations for the mill

were laid before sufficient investigation of the character of the stone. When more of the rock was uncovered it was found to contain some interbedded high- and low-magnesian strata. Moreover, the beds were so intricately folded that it was impossible to obtain stone suitable for cement manufacture except by hand sorting. The company abandoned the project and the property fell into the hands of a local bank that organized the Industrial Limestone Co. The quarry was worked for a few years, making a high grade lime of some of the best stone, shipping some low-magnesian stone to nearby cement plants and crushing the dolomitic and poor grade of stone for road metal.

The low-magnesian stone is gray, soft and generally finely laminated. The dolomitic beds are compact, steel-blue when fresh and white when weathered. The dolomite beds have been fractured and contain much vein quartz and calcite. Some beds contain much flint. The quarry is about 600 by 200 feet and has a face about 100 feet high. It has been abandoned for years and is now filled with water.

Illustrations and analyses of 21 samples have been published elsewhere.[29] In these the silica ranged from 2.42 to 7.46 percent, $Al_2O_3 + Fe_2O_3$ from 0.24 to 17.78, $CaCO_3$ from 38.10 to 92.45, and $MgCO_3$ from 1.25 to 40.90. The samples analyzed were selected to show the variations in the character of the stone in one portion of the quarry. By careful selection of stone and efficient burning, a high-grade lime was produced at this place.

It is inadvisable to present individual descriptions of the scores of small lime plants scattered through the limestone areas of the county. Although farmers gave some attention to the quality of the stone, more was directed to the location of stone easily quarried and near the place where it was used. Both good and poor stone was quarried and burned. These plants are now practically all in ruins, although occasionally some farmer will burn a few kilns of lime for local consumption.

At the writer's suggestion, S. H. Salisbury, Jr., and G. C. Beck analyzed numerous samples from five different quarries in the Beekmantown limestones of the region. From their published results[30] the following extracts are taken to show the variations in the chemical composition (particularly the MgO) of some of the Beekmantown limestones that have been so extensively quarried for lime.

Quarry A

Quarry A is situated in Northampton County three-eighths mile west of Georgetown on the Newcenterville road. The strata here are nearly vertical and vary in thickness from two to eight feet. Near the center some folding

[29] Miller, B. L., Limestones of Pennsylvania: Pennsylvania Topog. and Geol. Survey Bull. M 20, p. 590, plate 34, 1934.

[30] Jour. Ind. and Eng. Chemistry, vol. 6, pp. 837-851, 1914.

and faulting occur so that it is difficult to follow the strata to the top of the quarry.

Analyses of limestone from quarry A

Sample	Thickness of beds (feet)	MgO	$MgCO_3$	SiO_2	Al_2O_3+ Fe_2O_3	CaO
A1a	South face	15.41	32.20			
A1b	South face	17.14	35.84	5.82	1.23	28.19
A1c	South face	16.81	35.12			
A2	2 1/4	18.95	39.60			
A3	3 1/3	17.09	35.72			
A4	7 1/4	16.78	35.05	10.35	5.25	47.08
A5	3 1/6	18.00	37.64			
A6	3 1/3	18.45	38.54			
A7	6 1/2	18.48	38.74			
A8	4	17.32	35.20			
A9	2 1/4	17.56	36.65	7.35	3.85	29.56
A10	6 5/6	17.72	37.04			
A11	2 7/12	18.33	38.34			
A12	2	17.12	35.80			
A13	8 1/2	18.68	39.00			
A14	2 1/4	17.59	36.67			
A15	1 1/6	15.29	31.93			
A16	North face	18.40	38.47	8.92	2.90	27.48

Highest is A13, 18.68 per cent. Lowest is A15, 15.29 per cent. Greatest difference, 3.39 per cent. Average 17.51 per cent.

These results show quite small variation, considering the number of strata, the greatest difference being 3.39 per cent. The average of the CaO seems to be about 28.41 per cent. Sample A4 shows a very large increase in CaO with a drop of 0.8 per cent MgO from the average of the quarry. This large increase of CaO in sample A4 over the beds A1b and A9 on both sides of it is significant.

Quarry B

Quarry B is located in Northampton County, one-half mile north of Brodhead on the Nazareth turnpike. This quarry faces the west, is 700 feet long and about 30 feet high, with bedding and cleavage planes nearly indistinguishable. Samples were taken every 35 feet at various heights from the base.

Analyses of limestone from quarry B

Sample	Height from base (feet)	MgO	$MgCO_3$	SiO_2	Al_2O_3+ Fe_2O_3	CaO
B1	3	19.13	39.98	2.36	1.97	28.89
B2	10	20.49	42.83			
B3	20	18.68	39.04			
B4	15	19.94	41.68	7.70	3.85	28.29
B5	13	20.16	42.14			
B6	3	19.43	40.61			
B7	25	19.98	41.76			
B8	5	20.25	42.32			
B9	10	29.35	42.53			
B10	8	20.54	42.93			
B11	15	20.47	42.78	1.74	1.17	29.43
B12	10	19.75	41.28			
B13	25	19.88	41.55			
B14	7	19.29	40.32			
B15	7	20.37	42.57	2.45	0.93	29.50
B16	7	20.34	42.51			
B17	7	19.85	41.49			
B18	7	18.79	39.27			
B19	7	20.16	42.14			
B20	7	19.00	39.71			

Highest, B10, 20.54 per cent. Lowest, B3, 18.68 per cent. Greatest difference, 1.86 per cent MgO. Average 19.84 per cent MgO.

The results here, as might be expected from the structure, show less variation than in quarry A, while the average is 2.3 per cent higher. The greatest difference is only 1.86 per cent MgO, this quarry being the most regular in the distribution of the magnesia of any that we have analyzed. The lime content is also quite regular, the greatest variation of any of the constituents being in the percentages of silica.

Quarry E

Locality E is located in Northampton County, one-eighth mile west of quarry B, being a cut of the Lehigh & New England Railroad. The beds are sharply inclined to the north.

Analyses of limestone from locality E

Sample	Thickness of beds (feet)	MgO	$MgCO_3$	SiO_2	$Al_2O_3+Fe_2O_3$	CaO
E1		16.97	35.47	12.03	4.06	29.03
E2	2/3	15.00	31.35	8.71	4.53	28.26
E3	2 5/6	11.45	23.93	12.25	1.30	16.62
E4	1 1/2	14.59	30.49			
E5	1 2/3	13.60	28.42			
E6	4 1/6	13.87	28.99	8.08	5.39	24.54
E7	1 1/2	7.58	15.85			
E8	4 1/3	12.65	26.44			
E9	1 1/2	15.77	32.96			
E10	2/3	14.71	30.74			
E11a	6 1/6	16.38	34.23			
E11b	6 1/6	13.18	27.55	21.52	8.10	18.08
E12	1	6.70	14.00			
E13	1 5/6	14.64	30.60			
E14	1/4	14.51	30.33			
E15		18.36	38.37	5.20	3.08	31.42
E16	2 5/6	16.01	33.45	2.55	3.76	33.63
E17	2 1/6	9.75	20.38			
E18	6 2/3	16.86	35.24			
E19	9	14.84	31.02			
E20		14.76	30.85			

Highest E15, 18.36 per cent MgO. Lowest E8, 12.65 per cent MgO, excluding samples 3, 7, 12, 17. Greatest difference, 5.71 per cent MgO. Average, 15.10 per cent MgO.

Samples 3, 7, 12, and 17 are excessively low in magnesia. Inspection of the hand specimens shows that 3 and 17 contain crystals of calcite throughout the groundmass, while 7 and 12 are clay shales and give off an earthy odor when breathed upon.

The difference in content of lime is also to be noted, ranging from 16.62 per cent in E3 to 33.63 per cent in E16, a difference of 17 per cent. There is also considerable variation in the silica.

Limestones for flux.—When the local iron ores were being mined and smelted in the furnaces scattered along the Lehigh River and in the Saucon Valley, many limestone quarries were operated in regions nearby to supply the necessary fluxing stone. Some of these along the Saucon Creek and the Lehigh River were worked for fifty years or more and are of large size. Practically all the stone used was highly magnesian. The silica and alumina also were high in some quarries. The proximity of the quarries to the furnaces and the consequent low transportation costs generally made the use of rather poor stone profitable.

There are large abandoned quarries near these old furnaces, particularly near Hellertown, Freemansburg and Glendon. The Bethlehem Steel Co. has long used local dolomitic limestones for part of their fluxing stone. In those plant operations where high-grade calcium limestones or low-silica dolomites are required, the product must be shipped from regions beyond the county. This company long operated a quarry near Redington in the Tomstown limestone and now works an extensive quarry between Bethlehem and Freemansburg on the left bank of the Lehigh River.

Besides these quarries the same company has prospected in several other places. Some properties have been thoroughly investigated by diamond drilling and the core samples analyzed. In some cases only silica has been determined.

Occasionally limestones from this county have been shipped to adjacent areas. The Parryville Iron Co. at Parryville, Carbon County, long obtained fluxing limestones from a quarry near Northampton

Nearly all the quarries from which stone was obtained for flux were along the railroads, and spurs were built into the quarries. In many places better material might have been obtained elsewhere, but the cost of hauling the stone to the railroads was prohibitive.

Although the limestones have been and still are being used extensively for flux, some objectionable features have inconvenienced the operators, the worst of which is the presence of layers high in silica. Most of the furnace operators prefer limestones that contain strata with less than 4 percent silica, and where shaly or sandy strata are interbedded with the limestones it is necessary to separate these beds as waste rock. The presence of solution cavities filled with clay, which are common in regions where the rocks have been deformed or shattered by earth movements, is equally objectionable. Clay filling deep solution pockets in the surface is also present in places, and the removal of this overburden greatly increases the cost of quarrying.

Analyses of local limestones on a later page have been selected from hundreds made by the Bethlehem Steel Co., the Crane Iron Co., and the Thomas Iron Co., all of which have been largely dependent upon the limestones of the region. Some of the analyses are from places prospected for fluxing stone but never used for that purpose. It must be clearly borne in mind that practically every quarry shows variations in composition from bed to bed and not uncommonly in the same bed within relatively short distances.

The largest quarry now being operated in the region for limestone flux is owned by the Bethlehem Mines Corporation and is near Freemansburg, immediately across Lehigh River from the Bethlehem Steel Co. plant. The rock belongs to the Allentown formation. The quarry

is about 1,500 feet long and has been advanced into the hillside about 600 feet. The height of the quarry face is about 70 feet. The rock is hard dolomite considerably shattered. Although the strata are both folded and faulted the general strike is northeast with an average dip about 20° NW. The average composition is about as follows: $CaCO_3$ 53 percent, $MgCO_3$ 41, $Al_2O_3 + Fe_2O_3$ 2, SiO_2 4.

The quarry was acquired by the present owners in 1916. Previously it had been operated for commercial stone and for lime burning by the Chapman Quarries Co. The larger sizes, 2½ to 6 inches, are used for blast furnace flux and the smaller sizes, graded into nine classes between dust and 2½ inches are washed and sold for commercial purposes.

The proximity of the quarry to the blast furnaces is the most desirable feature of this operation. The stone is transported across Lehigh River and the railroads to the furnaces by aerial tram. The greatest obstacle in the operation of the quarry has been the heavy clay overburden and the occasional deep clay pockets and rotten stone. The quarry and crushing plant are well equipped with electric shovels, steam haulage to the crushing plant, crushers, screens and washing plant. The estimated annual production is 360,000 tons of fluxing stone and 250,000 tons of washed commercial stone. Since 1916, the quarry has furnished 2,930,000 tons of fluxing stone and 1,340,000 tons of commercial crushed stone.

The Bethlehem Steel Company at one time obtained similar fluxing stone from quarries at East Allentown and some Tomstown dolomite, in which there was considerable shaly material, from near Redington. These quarries are now abandoned.

One of the extensive quarries once worked for flux, but abandoned perhaps forty years ago, is the Glendon quarry along Lehigh River and Central Railroad of New Jersey, about two miles southwest of Easton. It was formerly owned by the Glendon Iron Works and worked to supply their furnaces with fluxing stone. The quarry is approximately 1,200 feet long, has been advanced into the hillside about 400 feet, and has a face about 175 feet high. The flat quarry floor is just about level with the railroad tracks. The stone is a dolomite belonging to the Allentown formation. The beds are moderately thick, averaging about one foot, but with some two-foot beds. Some layers contain *Cryptozoon proliferum.* Black shale bands are few. Near the front of the quarry the beds are complexly folded and faulted; farther back they are fairly regular but show one broad anticline. The general strike is about N. 52° E. with a dip of 20° SE. The overburden was thin, probably averaging no more than three or four feet.

Limestone for crushed stone.—As in other parts of the State, the Cambro-Ordovician limestones of this section have been used extensively for roads and for concrete aggregate. Except for occasional shaly bands, practically all the stone will meet the rigid specifications of the State Highway Department. Scores of quarries have been opened to supply local demands but most of them are of moderate size. Some fairly large quarries have been developed near the larger boroughs to supply the demands for concrete material.

In the vicinity of Easton, a few quarries have been worked for crushed stone for general concrete and highway use. Along the Delaware River road below Easton, the Tomstown and Allentown limestones have been worked in several places. Most of these were first opened to get stone for burning and have long since been abandoned. One of these just below Raubsville is of large size. The only active quarries near Easton now are two that are producing crushed stone only. William Roberts is operating a quarry about one-fourth mile south of the Lehigh Valley Railroad bridge. The stone is a bluish-gray dolomite with a few shale partings. Some oolitic beds and black flint concretions are noticeable. The quarry face is about 100 feet high. The strata are folded but in general dip gently to the north and east. The beds are fairly thick. The quarry is equipped with a steam shovel and two crushers. The capacity is said to be 500 tons per day. The stone is used for highways and concrete structures.

The John Walz quarry is along the Delaware River about a mile below the Lehigh Valley Railroad bridge. The stone is a hard dolomite suitable for crushed stone. The quarry face is about 70 feet high.

In recent years, C. Warne has worked the 25th Street quarry which is about half a mile northeast of the old Glendon quarry. The stone is a fine-grained dolomitic, siliceous limestone of the Allentown formation and contains *Cryptozoon proliferum*. Some of the beds are from three to six feet thick. The strike is N. 65° W. and the dip 15 NE. The quarry is about 150 feet long, 100 feet wide, and has a face 100 feet high. The stone is crushed and sized for road metal and concrete work.

North of Easton, there are old lime quarries, almost any of which might be worked for crushed stone if the market conditions should warrant.

Near Freemansburg several quarries for crushed stone have been worked in the Allentown dolomitic limestones.

About Bethlehem there is demand for considerable crushed stone and several quarries have been worked for this material. The large quantity now being produced as a by-product by the Bethlehem Mines Corporation at their fluxing-stone quarry between Bethlehem and

Freemansburg prevents the opening of many other quarries. Lerch's quarry along Monocacy Creek just north of Bethlehem, recently worked by T. H. and C. H. Groman, has long been worked for crushed stone. The stone belongs to the Allentown formation and is a hard dolomite with some sericite along the bedding planes. *Cryptozoon proliferum* is abundant through the quarry and ripple marks, oolite and edgewise conglomerate are common. A fine anticlinal fold and a prominent fault are exposed.

The Beekmantown limestone has been crushed for road metal and for concrete along the Tatamy-Nazareth road, just west of Tatamy and about a mile east of Nazareth. The stone is interbedded high- and low-magnesian. Both varieties are suitable for crushed stone. The Trumbower Co., Inc. has been the principal operator in this area.

In the vicinity of Northampton and Catasauqua, quarries in the Beekmantown were once worked for fluxing stone for blast furnaces at Hokendauqua, Catasauqua, and Parryville. Later they were used for cement rock where the high-calcium beds could be separated. The only one still in operation is that of the Northampton Quarrying Co. about one mile southeast of Northampton. The quarry contains both low-magnesian stone that is at times separated and sold to the nearby cement companies, and hard, dark blue, dolomitic limestones that are suitable only for crushed stone but particularly adaptable for that use. In general the beds dip steeply to the south but folds and faults produce a complicated structure. The structure, however, is simple as compared with a quarry about half a mile to the west where the beds have been so intricately folded that it is extremely difficult to determine what has taken place. The quarry face is about 90 feet high. The clay overburden over part of the quarry is heavy. Some analyses of the stone sent to blast furnaces are given in the table of analyses at the close of this chapter. Some of the stone sent to cement plants contains over 89 percent $CaCO_3$ and 3.44 percent $MgCO_3$.

Limestones for cement.—Since the Jacksonburg formation in certain places contains too small an amount of $CaCO_3$ for the manufacture of portland cement, several companies have been compelled to bring in some high-grade stone from other sections. Naturally, they have searched for stone of similar quality in proximity to their operations. Some suitable stone has been obtained in the Beekmantown, which is in contact with the Jacksonburg, but interbedding of this high-grade stone with magnesian strata has made their separation difficult. In 1938 a quarry in Berks County is producing low-magnesian stone from beds thick enough to permit steam shovel operations. So far,

no similar occurrence has been found in Northampton County. With some Beekmantown limestone containing upwards of 90 percent $CaCO_3$ and very little $MgCO_3$, it is only natural that money be spent in search of workable thicknesses of this kind of rock. The writer knows of three places where diamond drilling was done for this purpose. In each case it was found that the interbedding of the high-calcium and the dolomitic limestones made it impracticable to open a quarry for low-magnesian stone. These three localities were southeast of Northampton, southwest of Stockertown and east of the road between Newburg and Nazareth.

Along the Central Railroad of New Jersey a quarter of a mile north of Catasauqua the Lawrence Portland Cement Co. operated a Beekmantown limestone quarry for many years. The material low in magnesium carbonate was shipped to the cement plant at Siegfried, and that which contained too much magnesium for cement was sold to the Crane Iron Co. for flux. At times the company was able to use 75 percent of the output for cement, but at other times scarcely 25 percent. In most places the content of magnesium carbonate was fairly uniform in each bed of rock, but certain strata that were suitable for cement in parts of the quarry changed in composition in other parts sufficiently to be undesirable. Under the guidance of the chemist the quarrymen learned to detect the difference in appearance of the rocks low and high in magnesium carbonate, so that their separation was easy. Naturally, steam shovels could not be used, as the different kinds of rock were thrown down together in blasting. The following analyses of samples, taken at approximately equal distances from the northwest corner in turn along the north, east, and south faces, were furnished by the Lawrence Portland Cement Co. These show the best stone. Other layers contained much more $MgCO_3$.

Analyses of limestones in quarry north of Catasauqua.

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	9.02	7.82	12.91	12.38	12.81	7.43	13.90	5.56	1.94	5.18	5.70
$Al_2O_3+Fe_2O_3$	3.95	2.14	4.95	5.09	5.41	2.63	4.76	1.87	1.22	3.05	2.85
$CaCO_3$	82.12	85.50	79.65	79.03	75.50	85.32	76.94	87.23	92.57	88.30	85.63
$MgCO_3$	4.31	3.44	2.98	3.35	6.07	4.07	4.73	4.53	5.10	3.13	6.04

In other places in the county limited amounts of low-magnesian limestones from the Beekmantown have been obtained for shipment to the nearby cement plants.

In the small area of Franklin limestone outcropping along Monocacy Creek west of Pine Top there is some promising stone. A few years ago a quarry was opened along the creek by the Monocacy Stone Co. and considerable stone was shipped to some of the cement mills in the vicinity that require additional high-calcium limestone low in mag-

nesia. The rock in this quarry is so crushed and sheared and contains such an unusually large amount of silicate minerals that it was necessary to discard a considerable quantity of the stone, and the quarry did not prove profitable. From the surface indications it would seem probable that much better material could be obtained from other parts of the property. An average analysis of fifty tons of stone gave the following results: $CaCO_3$ 90.49, $MgCO_3$ 2.10, SiO_2 7.39.

More complete analyses are given in the description of the Franklin formation on a previous page.

Additional analyses of Cambro-Ordovician limestones

Tomstown

	1	2	3	4	5	6	7	8	9
SiO_2 (Ave.)	10.14	8.76	9.22	3.80	7.39	1.80	3.80	15.84	4.95
(Max.)	16.84	18.25	13.14	5.15	—	—	4.90	—	—
(Min.)	3.04	1.44	3.61	2.97	—	—	2.80	—	—
Al_2O_3 (Ave.)	—	—	—	—	—	—	—	—	—
(Max.)	—	—	—	—	—	—	—	—	—
(Min.)	—	—	—	—	—	—	—	—	—
Fe_2O_3 (Ave.)	—	—	—	—	—	—	—	—	—
(Max.)	—	—	—	—	—	—	—	—	—
(Min.)	—	—	—	—	—	—	—	—	—
$Fe_2O_3+Al_2O_3$ (Ave.)	4.35	3.53	—	—	—	2.40	2.35	14.90	1.28
(Max.)	7.01	6.43	—	—	—	—	2.70	—	—
(Min.)	1.86	1.34	—	—	—	—	1.70	—	—
$CaCO_3$ (Ave.)	49.23	49.70	—	—	90.49	53.45	52.40	40.72	49.57
(Max.)	52.30	53.70	—	—	—	—	53.62	—	—
(Min.)	44.62	42.70	—	—	—	—	51.01	—	—
$MgCO_3$ (Ave.)	38.52	39.07	—	—	2.10	42.54	41.54	28.54	37.96
(Max.)	42.48	43.31	—	—	—	—	42.79	—	—
(Min.)	34.29	32.35	—	—	—	—	40.88	—	—
Phosphorus (Ave.)	—	—	—	—	—	.009	—	—	.003
(Max.)	—	—	—	—	—	—	—	—	—
(Min.)	—	—	—	—	—	—	—	—	—
Sulphur (Ave.)	—	—	—	—	—	—	—	—	—
(Max.)	—	—	—	—	—	—	—	—	—
(Min.)	—	—	—	—	—	—	—	—	—

Additional analyses of Cambro-Ordovician limestones

Allentown

	10	11	12	13	14	15	16	17	18	19	20
SiO_2 (Ave.)	7.02	5.57	3.29	5.12	3.61	5.78	7.70	2.12	4.72	2.40	4.70
(Max.)	14.47	8.95	6.23	6.25	11.92	9.78	16 34	—	5.61	—	7.70
(Min.)	3.53	3.82	2.39	4.00	0.82	1.24	3.28	—	2.51	—	2.20
Al_2O_3 (Ave.)	—	—	—	—	—	—	—	—	—	1.70	—
(Max.)	—	—	—	—	—	—	—	—	—	—	—
(Min.)	—	—	—	—	—	—	—	—	—	—	—
Fe_2O_3 (Ave.)	—	—	—	—	—	—	—	—	—	1.98	—
(Max.)	—	—	—	—	—	—	—	—	—	—	—
(Min.)	—	—	—	—	—	—	—	—	—	—	—
$Fe_2O_3+Al_2O_3$ (Ave.)	1.89	—	2.0	—	—	2.64	4.44	2.24	4.15	—	3.01
(Max.)	—	—	—	—	—	4.20	6.22	—	9.20	—	3.84
(Min.)	—	—	—	—	—	1.92	5.10	—	1.53	—	2.38
$CaCO_3$ (Ave.)	50.49	—	—	—	52.60	50.18	50.31	54.30	29.98	53.56	50.92
(Max.)	—	—	—	—	55.00	53.36	54.14	—	32.21	—	55.67
(Min.)	—	—	—	—	47.50	47.05	42.19	—	28.49	—	47.03
$MgCO_3$ (Ave.)	41.04	—	—	—	42.30	39.01	37.03	41.00	18.29	38.85	41.36
(Max.)	—	—	—	—	43.50	45.66	—	—	21.27	—	43.21
(Min.)	—	—	—	—	34.00	38.40	—	—	15.36	—	41.18
Phosphorus (Ave.)	—	—	—	—	—	—	—	—	.010	—	—
(Max.)	—	—	—	—	—	—	—	—	—	—	—
(Min.)	—	—	—	—	—	—	—	—	—	—	—
Sulphur (Ave.)	—	—	—	—	—	—	—	—	.036	—	—
(Max.)	—	—	—	—	—	—	—	—	—	—	—
(Min.)	—	—	—	—	—	—	—	—	—	—	—

Additional analyses of Cambro-Ordovician limestones

		Allentown				Beekmantown					
		21	22	23	24	25	26	27	28	29	30
SiO_2	(Ave.)	3.48	2.58	6.88	3.60	5.84	7.75	4.74	9.39	7.99	2.32
	(Max.)	——	2.73	——	5.68	5.84	11.90	7.04	15.93	11.24	5.20
	(Min.)	——	2.43	——	1.12	3.91	4.18	2.73	4.61	5.50	0.90
Al_2O_3	(Ave.)	——	——	3.46	——	——	——	——	——	——	0.96
	(Max.)	——	——	5.37	——	——	——	——	——	——	1.56
	(Min.)	——	——	2.38	——	——	——	——	——	——	0.66
Fe_2O_3	(Ave.)	——	——	——	——	——	——	——	——	——	0.74
	(Max.)	——	——	——	——	——	——	——	——	——	.092
	(Min.)	——	——	——	——	——	——	——	——	——	.056
$Fe_2O_3+Al_2O_3$											
	(Ave.)	2.18	11.97	——	2.01	2.14	3.28	2.30	3.72	3.33	——
	(Max.)	——	14.87	——	2.56	3.44	4.74	4.99	7.89	4.34	——
	(Min.)	——	9.07	——	1.60	1.70	2.14	1.00	2.42	2.41	——
$CaCO_3$	(Ave.)	52.77	52.36	47.21	——	73.42	68.50	82.43	71.44	66.24	54.13
	(Max.)	——	53.48	48.12	——	82.64	86.63	91.16	85.60	82.37	55.42
	(Min.)	——	51.25	45.96	——	59.04	50.10	55.44	61.17	52.60	52.91
$MgCO_3$	(Ave.)	40.84	29.99	40.49	——	18.35	19.77	10.26	15.33	21.49	41.84
	(Max.)	——	31.47	41.63	——	34.82	39.40	37.94	28.62	33.30	42.92
	(Min.)	——	28.51	38.54	——	10.68	4.02	1.66	3.67	4.24	40.39
Phosphorus											
	(Ave.)	——	.012	——	——	——	——	.009	.014	——	——
	(Max.)	——	——	——	——	——	——	.012	.020	——	——
	(Min.)	——	——	——	——	——	——	.007	.010	——	——
Sulphur	(Ave.)	——	.041	.021	——	——	——	.026	——	——	——
	(Max.)	——	——	.014	——	——	——	.010	——	——	——
	(Min.)	——	——	.039	——	——	——	.040	——	——	——

Analyses 1-5, 10-16, 25-28 by Bethlehem Steel Company

1. Redington quarry, Bethlehem Steel Co. (average of eight samples).
2. General Crushed Stone Co., Redington (average of six samples).
3. Island Park limestone quarry (average of seven samples).
4. One mile northeast of Hellertown (average of three samples).
5. Deck Farm on Lehigh & New England R. R. three miles from Bethlehem.
6. Thomas Iron Co. property, Island Park.
7. Best property adjoining Island Park plant (average of seven samples).
8. Same property as 7 (analyses from shaly layer).
9. Browns quarry, alongside public road above Raubsville (average of three samples).
10. Henry Schweitzer farm (average of five samples). One mile northwest of Freemansburg.
11. Clause & Laubach (average of eight samples). One mile north of Freemansburg.
12. Firmstone, near Glendon Station, C. R. R. of N. J. (average of nine samples).
13. One and three-quarter miles west of Hellertown (average of two samples).
14. Quarry one mile west of Freemansburg (average of eight samples).
15. One-half mile north of Freemansburg (average of twenty-one samples).
16. One mile north of Freemansburg (average of six samples).
17. Freeman quarry, Freemansburg.
18. Hellertown quarries (average of six samples).
19. Apples quarry, Hellertown (one sample).
20. W. H. Rudolph property two miles from Bethlehem on Bath R. R. (average of four samples).
21. Gangwere's quarry at Bingen (one sample).
22. William Chapman quarry between Bethlehem and Freemansburg (average of two samples).
23. Edward and John Wagner, west of Saucon Furnaces on Saucon Creek, Hellertown (average of five samples).
24. Preston Riegals quarry on west side of Saucon Creek, Hellertown (average of ten samples).
25. Weaversville—Horace Boyd and W. H. Richards (average of five samples).
26. Reyer quarry one mile southeast of Northampton (average of nine samples).
27. T. Fogel farm near Hecktown on Lehigh & New England R. R. (average of ten samples).
28. Trumbower quarry about one mile east of Nazareth (average of eleven samples).
29. Test hole 2. Fulmer farm one mile east of Tatamy (average of eight samples).
30. Wagner limestone quarry, operated by Dr. Heller (average of seven samples).

Building Stone

Although stone has been quarried in many places in Northampton County, no important building stone industry has ever been developed, other than the roofing slate industry which is discussed elsewhere. Locally, the Cambro-Ordovician limestones, the Hardyston sandstones and quartzites, the Shawangunk sandstones and conglomerates, and the pre-Cambrian gneisses have all been used but only in small quantities. Waste slate blocks have been used for the construction of small buildings near some of the slate quarries. After exposure to weathering these building present a bizarre appearance as the bands or ribbons become objectionably prominent.

Limestone.—Northampton County contains some attractive stone houses built before 1850. Since then limestones have been quarried rarely for building purposes. The limestones that have been used in residences and barns have come mainly from local quarries that have been worked for lime.

The principal reason for the limited use of limestones for building is the expense of dressing the stone. The great compression that all of the limestone strata of the region have suffered, developed several systems of joint fractures along which the stone breaks. Rectangular blocks can seldom be obtained by the ordinary quarry methods. Both thin and massive beds yield angular blocks of all shapes and sizes. Masonry construction under these conditions is unduly expensive.

Also, the shallow-water origin of the limestones resulted in rough surfaces, interbedded shaly laminæ and beds of varying thickness. Veins of quartz and calcite are numerous where the rocks were shattered by folding and faulting. In places secondary flint nodules are abundant.

The limestone has been used in irregular blocks, called "rubble construction;" in rectangular blocks of fairly uniform thickness, designated "coursed ashlar;" and in rectangular blocks of varying thickness known as "random or broken ashlar." Most of the old stone houses have walls several feet thick, with rough-shaped blocks in mortar inside the more neatly built external walls. In some cases the masonry of the outer walls is of poor construction and the exterior has been covered with plaster.

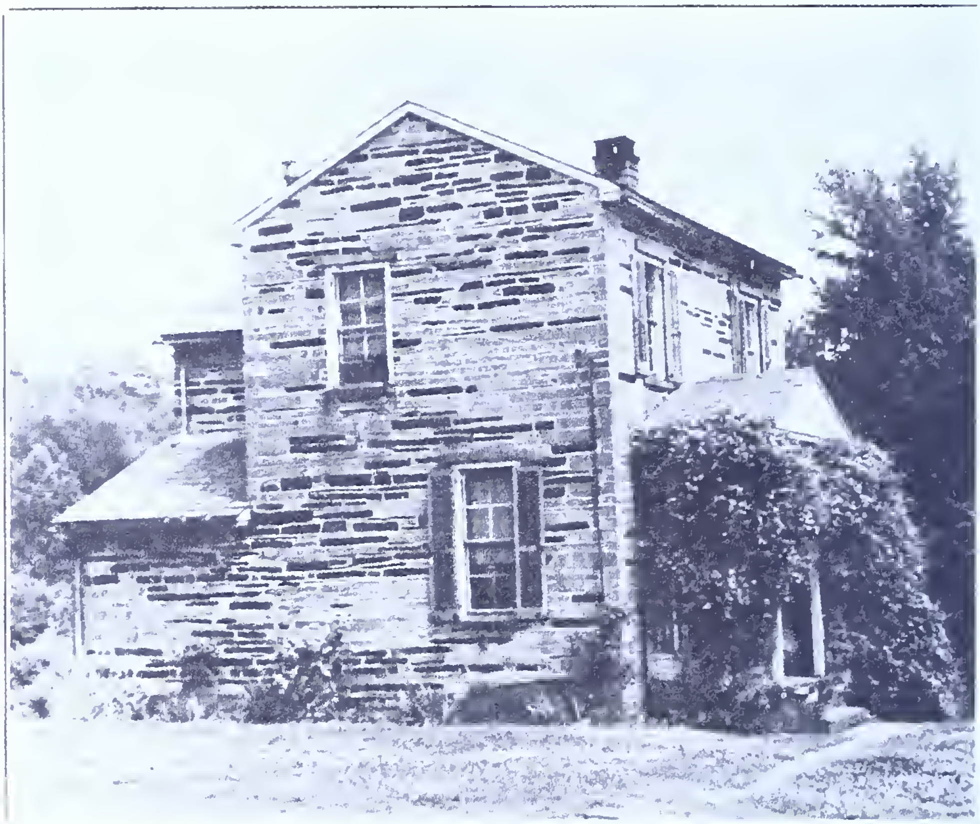
To satisfy the small continuing local demand for limestone for buildings and walls, some quarries now operated for crushed stone will set aside the occasional desirable well-shaped blocks that may be shot down in blasting. In this way some fine building stone has been obtained at reasonable expense. It is probable that local limestones

A. Williams Church, one mile east of Lower Saucon, built of gneiss.

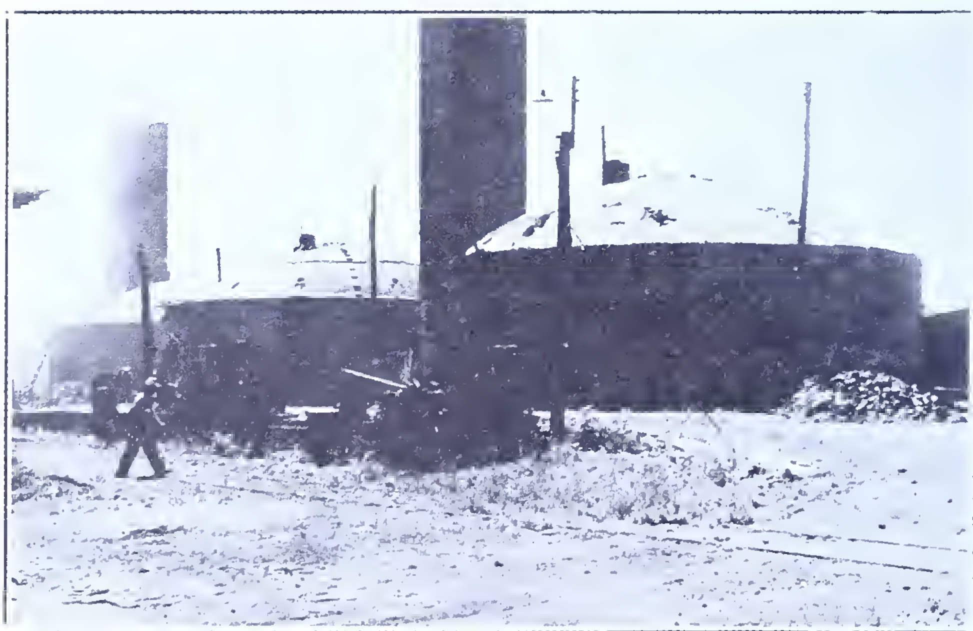
Photographs by J. M. Lohse.

B. Detail of same.

PLATE 24.



A. House constructed of waste blocks of slate. Chapmans.



B. Kilns of Saucon Valley Brick Co., Bingen.

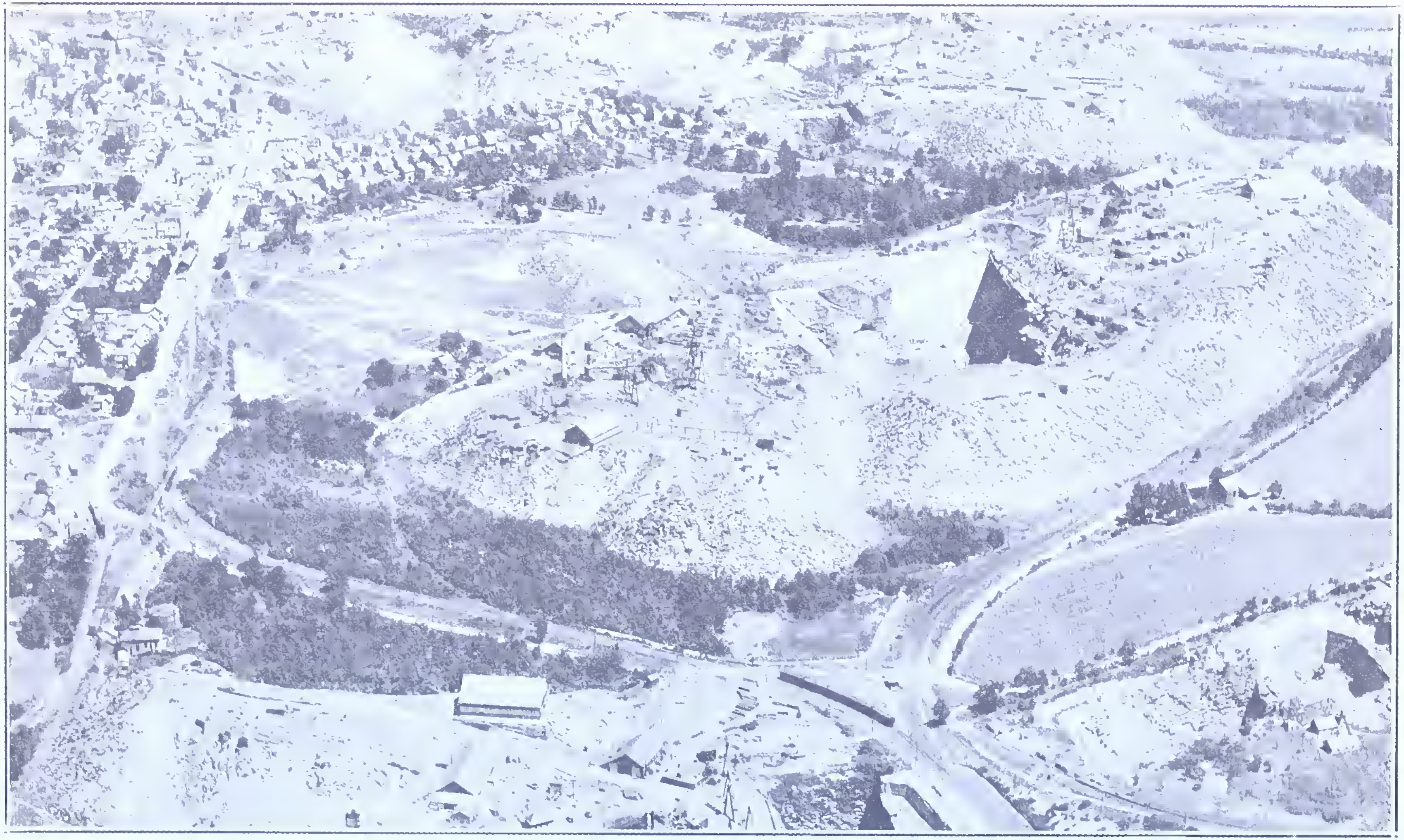
will long be used in small amounts for construction of buildings, bridges and walls, but the quarrying of such material is apt to be incidental to other purposes.

Sandstone and quartzite.—The Hardyston formation contains siliceous beds that are commonly known as quartzites, although generally the degree of metamorphism is so slight that they are more appropriately called sandstones. They rest unconformably on the gneisses and now outcrop on the lower slopes of the gneiss hills. With the exception of a small area on the south side of Camels Hump, they all lie south of the Lehigh River. This is the most attractive building stone in the county and the one most generally used at the present time.

These sandstones have been quarried in several places in Northampton County but not as extensively as in Lehigh and Berks counties. In recent years the only quarry operated lies on the hillside east of Hellertown, about one-fourth mile north of Lost (Hellertown) Cave. Earlier, this stone was quarried on the northeast side of South Mountain one and a half miles east of Lehigh University and on the west side of the Bethlehem Pike in Seidersville.

These sandstones were long known to the building trade as the Potsdam sandstone under the mistaken idea that they were of the same age as the Potsdam formation of New York State.

The quarry east of Hellertown furnished the stone for several buildings on the Lehigh University campus. The Packard Engineering Laboratory is the best example. The quarry is on the lower slope of the west end of a gneiss hill. The beds form a surface cover to the gneiss, dipping to the west only slightly more than the slope of the hill, and having somewhat the same relationship as the shingles on a roof. The rock is a hard, compact stone composed of quartz sand grains with some quartz pebbles as much as one-fourth inch in diameter. A basal layer with pebbles up to two inches in diameter and with a dark-colored matrix is generally present but not used. When fresh, the rock is gray to bluish-white but a band of discoloration from one-eighth to one inch in depth has stained the stone to a ferruginous brown or red along bedding planes and joint cracks. This is due to the presence of numerous tiny cubes of pyrite that are almost invariably present in the unaltered stone. They may be seen with the naked eye but better with a hand lens. At one time builders sought the gray fresh stone but in recent years architects have expressed a decided preference for the discolored stone. The alteration has not weakened the stone to any appreciable extent.



Slate quarries near Pen Argyl.
Copyrighted photograph by Aero Service Corporation, Philadelphia, Pa.

In this quarry the beds vary in thickness from two to ten inches. The surfaces are fairly smooth and the joints regular, so that rectangular blocks of suitable size can readily be obtained. They are dressed easily.

Up to 1938 there has been little overburden, but if the working continues it will be necessary to remove an increasing thickness of soil and talus as the strata dip underground. Only about ten feet of bed is worked. The supply of easily quarryable stone is limited.

The Shawangunk sandstones and conglomerates of Kittatinny Mountain contain some stone suitable for building purposes but they have been little used. So far as known, no stone of this kind has ever been quarried in Northampton County. Some of the blocks from the talus slopes have been used but only in small quantities.

Gneisses.—Elsewhere in Pennsylvania, the pre-Cambrian metamorphic gneisses have been quarried extensively for structural stone but in Northampton County they have been used sparingly. This is mainly due to the fact that the expense of quarrying is high on account of the toughness of the rock. The initial expenditure involved in opening a quarry is also great on account of the decomposition of the exposed rock. On the surface the gneisses of all kinds are so broken by the action of frost or so greatly decomposed that much waste must be removed to reach good stone. Below the zone of freezing the stone is broken by joints into large irregular blocks that could be handled economically only by expensive mechanical equipment. The irregularity of the joints would cause an excessively large amount of rock to be discarded as waste, although this condition may not prevail everywhere. As large quantities of crushed rock for concrete and ballast are required in the industries of the region and in making permanent roads, market might be found for the rock that is unsuited for building stone.

The gneisses of the county furnish a wide variety of stones, ranging from dark-brown hornblendic to light granitic rocks, some of which are beautifully banded and others present a uniform appearance. In general the darker gneisses are more common in the eastern part of the county, especially near Hexenkopf Hill, and the lighter-colored ones are more abundant about Bethlehem and Hellertown.

The gneisses contain no objectionable minerals, except in a few localities where pyrite is a common constituent. The chemical and physical character of the rocks makes them very durable as building stones under all climatic conditions.

A few attractive residences, churches and barns in the county have been built of the local gneisses. In almost all of them, only loose

field stones were used and no quarries opened. The stone has been dressed for rubble construction.

There is little doubt but that high-grade building stone might be got in various places in the gneiss hills of Northampton County if the demand and market prices should warrant the expenditure of the rather large sum necessary for development and equipment.

Glacial boulders.—Some attractive walls and bungalows have been constructed of glacial and river cobbles such as are common in the terrace deposits of the Delaware River and in the glacial moraines and kames in the northeastern corner of the county. Ordinarily these cobbles have been utilized only for lining gutters.

Slate*

By Charles H. Behre, Jr., and Benjamin L. Miller.

The Lehigh slate district of Northampton and Lehigh counties has long been the leading slate-producing region of the United States. The slate industry for over 100 years has been the most important industry of nearly all the communities in the northern part of the county. A traveller passing through Wind Gap, Pen Argyl, Bangor, Danielsville or almost a score of other villages cannot fail to be impressed with the evidence of extensive slate operations as he views the numerous excavations and the "mountains" of waste rock that dominate the landscape.

From Pennsylvania quarries and mills all varieties of slate products except slate pencils are obtained. The list includes roofing slate, mill stock, marbleized slate, slate granules, and pulverized slate. "Mill stock" is a comprehensive term covering rough or finished slate that is used for structural purposes or in interior furnishings of buildings. It includes slate for structural and sanitary purposes (e. g., sinks, mantels, dripboards, shower stalls, toilet stalls, stair risers, insulating wall board, and the like), grave vaults and covers, billiard table tops, electrical insulation and switchboard material (together classed as "electrical slate"), blackboards and bulletin boards (lumped together under the trade term of blackboards), school slates, marbleized slate, crushed slate, and ground slate. Among the districts where slate is now being quarried the "soft" slate of the Lehigh-Northampton district yields all of these products; the Peach Bottom district and the "hard" belt in the Lehigh-Northampton district furnish today only

* NOTE: In 1933 this Survey published "Slate in Pennsylvania" (400 pp.), by Charles H. Behre, Jr. Most of the volume concerns the slate deposits and slate industry of Northampton County. Inasmuch as this report is still in print and readily obtainable, it would manifestly be inadvisable to republish any considerable portion of that volume here or to attempt to duplicate this work. For that reason the discussion here is brief and limited to only a few considerations. The account is written by Miller with quotations from Behre's report.

crushed slate, roofing slate, and slate for such structural and sanitary uses as will require no finishing, although finished structural slate and even blackboards were once prepared with the aid of diamond saws at the Chapman quarry in the "hard" belt. The great proportion of the slate production of the State is in the form of roofing slate.

Pennsylvania leads all other States in slate production. In 1937 the value of slate produced amounted to $2,735,744 or 49 percent of the value of all slate produced in the United States. Northampton County made 90 percent of the output.

In 1937 Northampton County quarries produced about 55 percent of the roofing slate sold in the United States, and 57 percent of the mill stock.

Pennsylvania is the only State commonly producing blackboard slate, although very small amounts have come from other localities in certain years. The yield is entirely from the Lehigh-Northampton district. All of the production comes from the neighborhood of Bangor, of Pen Argyl and Wind Gap, or of Slatington, Berlinsville, and Slatedale.

History.—Fritts (1877) says that a company for quarrying slate in Northampton County was incorporated in 1805. Finch in 1824 reported that slate quarries had been opened "near the banks of the Delaware" but the product was regarded as inferior.

"... The first operation recorded was in the hard belt by a company from Baltimore which in 1828 began quarrying west of Laurys Station in Whitehall township, probably at the Rockdale quarry, Lehigh County.

"In 1831 slate was discovered on Benninger's farm, east of Slatington, and probably near the site of the present Genuine Washington quarries, but extensive quarrying on a commercial scale is not known to have been done here before 1844. In that year, according to tradition, the land mentioned was leased by William Roberts and Nelson Labar, who became interested in quarrying from seeing slate outcrops while on a walking trip from Easton to Mauch Chunk.

"About 1850 slate was discovered at Bangor by Robert M. Jones, the founder of Bangor, whose statue is seen at the Bangor High School, on the hill east of that city, where the masts of the Old Bangor quarry now stand. At this time, too, the Chapman quarries in the hard belt were developed, the charter of the present company being dated 1864.

"Thus by 1855 the slate quarry industry, stimulated by Welshmen who were instrumental in persuading experienced slaters from Wales to emigrate to this country, was already thriving and growing by leaps and bounds. Indeed in 1850 or thereabouts, Rogers, then State

Geologist of Pennsylvania, and his associates found five quarries in operation at Slatington and two more near the Delaware Water Gap,[31] one of the latter apparently being the Old Jersey quarry, east of Delaware River. Rogers even writes of one quarry as having been opened in 1812, but this statement is probably incorrect.

"By 1880, when Sanders studied the district for the Pennsylvania Geological Survey, slate quarrying was in full swing at all the present centers of production. Indeed in many cases Sanders reports large quarries that had been worked out and abandoned.

"In its subsequent growth the district has suffered the depressions and revivals experienced by the slate industry of the country as a whole. The introduction of channelling represented a marked advance and served as a stimulus; in 1863 it was first practiced in Vermont[32] and probably reached Pennsylvania a decade later. The appearance, however, of asbestos, paper and tar roofing materials shortly before the peak production in 1903, heralded a general decline in demand for roofing slate. At the same time, school slate consumption suffered greatly through displacement by cheap paper and at the hands of the sanitary experts of our public schools. This was accompanied by an intense price competition among the slate men themselves.

"There ensued, then, a period of marked distress in the industry. Labor costs had risen. Some of the old markets for slate products were on the wane with no possibility of any recuperation in the future; others were being invaded by substitute materials. Freight rates were prohibitive for distance shipments. Added to this, cost accounting was not recognized as furnishing a basis for proper sales prices; expenses were incurred in quarry operations, while prices were being cut in a manner wholly unjustified by the small return on the investment. Then came the greatest of all catastrophies to the industry, the World War. With the entry of the United States, slate quarrying was almost totally abandoned, being classed as unessential; labor was beyond reach. Immediately after our entry into the war the organization of the slate industry, so long projected and so long prevented by internal strife, took place to a considerable degree, and two large companies were formed, one to deal with structural products, the other with roofing slate."

During the past few years the slate industry has suffered greatly, owing to the general inactivity in the building trade. The introduction of the wire saw has been the means of reducing the waste, but investigations to find uses for the discarded rock have met with little success.

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[31] Rogers, H. D., Geology of Pennsylvania, vol. 1, pp. 258, 249, 1858.

[32] Merrill, G. P., Stones for Building and Decoration, John Wiley and Sons, New York, p. 104, 1910.

Behre's report contains individual descriptions of 178 quarries that have been operated in Northampton County, most of which, however, are idle.

Serpentine and Talc

The narrow band of serpentine that crops out along the southern slope of Chestnut Hill throughout its entire length continues a short distance across Bushkill Creek and across the Delaware River into New Jersey. Two other openings a short distance northwest of Chestnut Hill expose similar rock. This occurrence is famed for the variety of minerals that have been found here, some of which are extremely rare. These are described in the chapter on Mineralogy. The serpentine and talc have long been quarried in several places in Northampton County and in Warren County, N. J. Considerable asbestos is present but it is of no value.

The most complete report[33] thus far published appeared in 1911. Considerable information is abstracted from this report, which is out of print and scarce.

The rock in this belt ranges from soft greenish-white talc through light-green serpentine containing considerable light pink dolomite in places, to a mixture of dolomite and tremolite. Prof. Peck believed that the original rock was a pre-Cambrian dolomitic limestone such as contains the important zinc ore deposits at Franklin Furnace, N. J. This marble was intruded by pegmatites, of which one massive dike is exposed near the bottom of Williams quarry.

Quarries have been opened along the south side of Chestnut Hill, but mainly along the Delaware River and Bushkill Creek, both of which streams cut through the serpentine band. In 1938 the only quarry in operation is the one along the Delaware River Highway. It is owned and operated by C. K. Williams & Co., Easton. Quarrying is reported to have been done here in 1883. The beginning is not known.

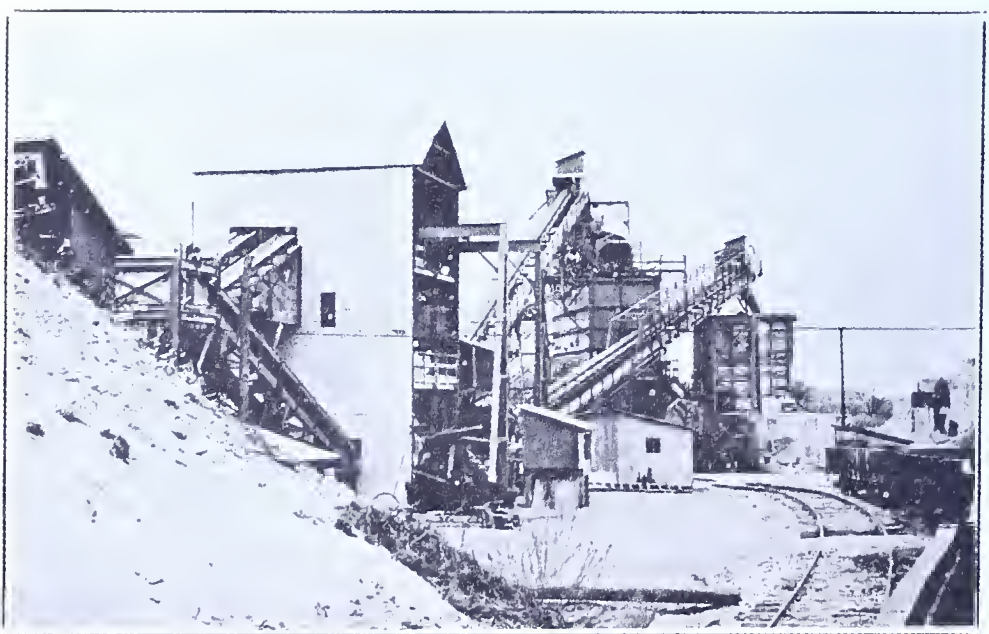
The rock in each of the quarries is of varied character, in mineralogical composition, in color, and in hardness. The serpentine ranges in color from dark olive-green to almost white. The white to pink dolomite is prominent in the quarry at times and on other visits may scarcely be noted at all. The talc, tremolite, asbestos and minor minerals are likewise irregularly distributed throughout the quarry.

The stone has been used for different purposes. Evidently the earliest use was for interior decoration. The term "verdolite" (coined from the terms verd-antique and dolomite) was coined for the

[33] Peck, Frederick B., Geology of the Talc and Serpentine Deposits of Northampton County: Pennsylvania Topog. and Geol. Survey Comm., Report 5, pp. 11-23, Harrisburg, 1911.

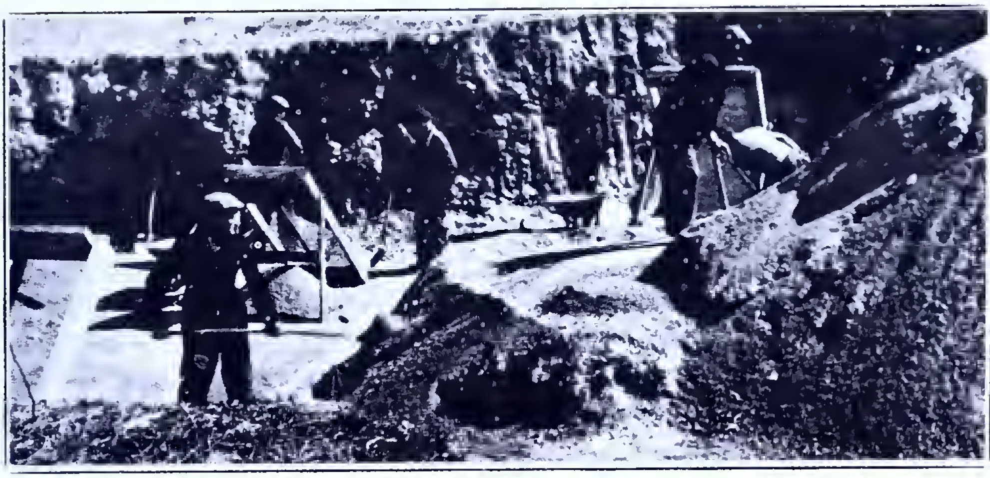
PLATE 26.

A. Williams' serpentine quarry, Delaware River road north of Easton.

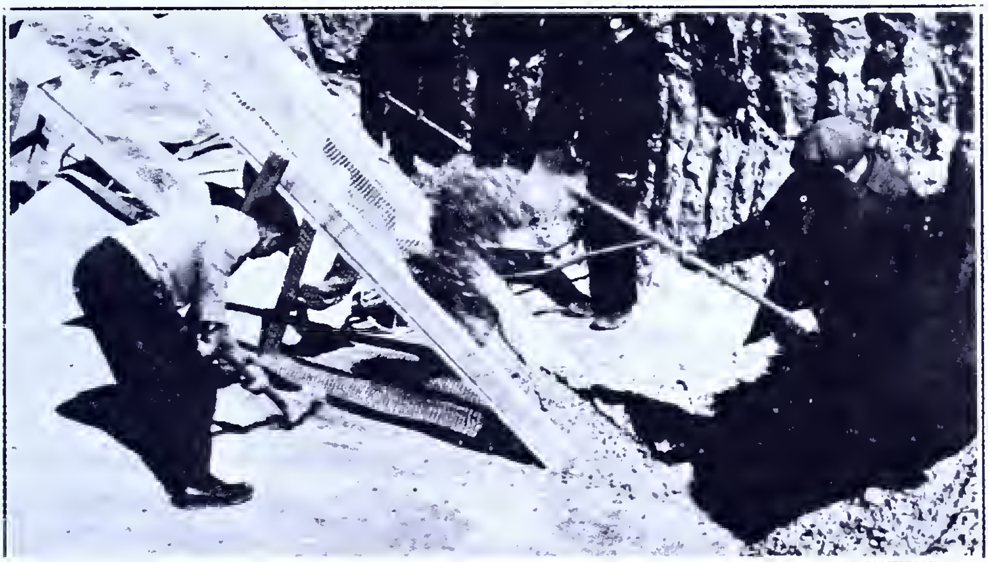


Photograph by Robins Conveying Belt Co.

B. Plant of Portland Sand and Gravel Co., Mt. Bethel.



A. Digging and screening decomposed gneiss for "sand." Morgan Hill.



B. Detail of screening.

C. Illinoian till containing glacial boulders. Zehnder Brick Co., South Easton. (Dark line is shadow of cable.)

most attractive variety consisting of light-green serpentine and pink dolomite. Peek says that some of the "blocks were said to have been sold in New York at from $2.50 to $10.00 per cubic foot in the rough, or . . . from $30.00 to $120.00 per ton." The various kinds of serpentine were also cut into decorative slabs for mantels, base-boards, and other structural uses. Beginning about 1905 H. A. Schweyer and Son operated for several years a quarry along the left bank of Bushkill Creek for the production of floor tile. The serpentine was cut into thin one-inch squares. These were polished and when set in cement or plaster produced a beautiful floor.

The irregular and heterogeneous character of the rock, the absence of bedding planes or regular system of joints always made it difficult to get slabs of any considerable size and also resulted in an undue amount of wastage. This waste material was ground for mineral filler.

At the Williams quarry the material is sorted into two classes. The harder rock, containing much tremolite, quartz or hard serpentine, is sorted out for coarse grinding in a mill at the entrance of the quarry. It is crushed and graded by screens into sizes ranging from one-eighth to one-half inch in diameter and marked for terrazzo. After being mixed with cement, polishing the surface brings out the attractive colors.

The fines from the terrazzo material and the softer rocks are pulverized for filler purposes at the West Easton plant of C. K. Williams & Co. The rock is ground and air-floated to a size that will pass through a 325-mesh screen. The product enters into a variety of manufactured articles such as paint, rubber, and paper.

It is reported that carefully picked material from some of the quarries has been used in the production of talcum powder. Probably this is true as it is possible to find considerable rock composed almost entirely of light-green to white talc.

Quartz-Sillimanite-Mica Schist ("Soapstone")

In several places in the areas of gneiss in the county there are rocks that contain large amounts of quartz, mica (sericite), and sillimanite. Rock in which the sericite is especially abundant feels "soapy," somewhat like talc, and it is locally known as soapstone. Actually it contains only minute amounts of talc. Under the misapprehension that the rock was soapstone, a quarry was opened in it southeast of Smith Island (Island Park). The rock was hauled from the quarry to Easton to be ground for paper filler. Similar material from Lehigh County used several years ago by the Bethlehem Steel Co. for furnace lining is reported to have been satisfactory for this purpose.

Sand and Gravel

The local demand for sand and gravel has resulted in the development of many deposits that in a less populous section would be disregarded. Four kinds of sand are dug, each of which is distinct in origin and occurrence and adapted more or less to different uses.

Decomposed gneiss.—The most unusual sand of Northampton County is that obtained where the lighter-colored quartz-feldspar gneisses have decomposed into a mixture of angular particles of quartz and impure kaolin. Technically, decomposed gneiss should not be called sand, but in this section, where such material is used as a substitute for the ordinary kinds of sand, the commercial usage seems to be justified. The alteration of the feldspar to kaolin and the oxidation and removal in solution of the hornblende and pyroxene causes the rock to disintegrate. As water carrying oxygen in solution is the most active factor in this change, the decomposition starts along the joint planes of the gneiss and gradually extends into the blocks bounded by these fissures. Near the surface the alteration is more complete, and the rock is soft enough to crumble into sand when disturbed. At greater depths many masses of partly altered rock are still so hard that they must be discarded when the material is quarried for sand. In some of these quarries these resistant blocks are passed through a rock crusher and screened, the finest portions being used for sand and the remainder for concrete work or road metal.

The gneiss sand pits, as shown on the map, lie along the slopes of the gneiss hills, especially near Bethlehem and Hellertown. Besides those shown on the map there are other openings where at times a few wagonloads of sand have been dug.

The pits that are opened along the sides of the mountains increase in depth as the work progresses, and in some of them a 60-foot face is obtained. In some places the rock is decayed sufficiently to furnish sand at depths of 100 feet or even more.

In most of the pits less than four feet of overburden must be removed. It is loamy clay and fresh gneiss boulders derived from the outcrops of gneiss higher up the mountain. The quarrying is done with pick and shovel, and the loose material is thrown against a sloping screen, the mesh of which differs according to the kind of sand desired. The particles that fail to pass through, roll to the bottom of the screen. By pounding these coarser fragments with the back of the shovel many of them can be disintegrated sufficiently to pass through the screen when they are again thrown against it. The tough pieces are thrown aside as waste or put through a stone crusher.

In some of the pits the decomposition of the gneiss is very irregular, and certain parts of the pits must be abandoned on account of the large amount of waste rock. In one place the gneiss may be thoroughly decomposed to a depth of fifty feet, and close-by hard fresh rock may come within a few feet of the surface. A few pits contain dikes of basic rock, which must be discarded. In a pit in Bethlehem two dikes of such rock carrying much biotite caused considerable inconvenience, as the material resulting from their decomposition was worthless and had to be separated from the other sand.

The gneiss sand is used for a variety of purposes. It is well adapted for a molding or core sand on account of the kaolin, which acts as a binder, and large quantities have been used by the furnaces, foundries, and pipe mills of the region. For plaster and mortar it is less desirable, as the presence of the kaolin is detrimental, but this is partly counterbalanced by the sharp angularity of the grains of quartz, which increases the strength of the plaster or mortar. The decomposed gneiss has been used widely as a building and brick sand throughout the region. The coarse material has been used extensively in concrete work and to a less extent for road metal.

The prices of the sand depend upon both the quality and competition. The waste material used for road work sells for a very low price. The industry is almost entirely local, although some sand has been shipped to foundries and furnaces outside the county. The production, which varies greatly from year to year, has been small recently.

Glacial sand and gravel.—Although an ice sheet covered almost all of Northampton County, workable deposits of glacial sands and gravels are comparatively few except in the vicinity of the Delaware River where they occur as terrace and kame deposits. Most of the glacial deposits of the region consist of clay and boulders.

The most extensive sand and gravel deposits of the county are the kame deposits along Jacoby Creek west and north of Mt. Bethel. Thick, poorly stratified and sorted deposits of sand, gravel, cobbles and boulders occur there. The maximum thickness is not known but a face eighty feet high was worked at one point. The materials occur in lenses and layers of varying thickness and areal extent. In every working the character of the face changes as work progresses. At one time sand may predominate, and a short time later the coarser material may be more abundant.

The pebbles and larger stones are mostly hard siliceous sandstone and conglomerate, yet mixed with them are shale, slate and limestone. Impure limestones of the Onondaga, with the characteristic flint nodules and bands, are conspicuous, and material from almost every

formation of the Silurian and Devonian that is represented in the Delaware River basin north of this locality can be recognized. Some boulders are huge. One measured fifteen feet in diameter and bore innumerable glacial striæ. Some are highly fossiliferous. Students could scarcely find a more favorable place for studying sedimentary petrology. Most of the stones are well rounded, indicating that running water was in large part the transporting agent.

In deposits of this character it is possible to produce various sizes of materials to meet a variety of demands. The process of preparation is well illustrated by the only plant now in operation in the region. This is the plant of the Portland Sand and Gravel Co.[34] located about half a mile west of Mt. Bethel.

The material is excavated by two electric shovels, loaded into trucks and hauled to the plant. The present working face is thirty to forty feet high. The largest boulders are discarded in the pit. The material dumped into a hopper over a grizzly that rejects stones over fifteen inches, passes through a jaw crusher. Thence through screens and crushers with transportation by belt conveyor from place to place, the material is sized and sorted into grades as the market requirements and specifications need. At one stage of screening, jets of water under pressure wash any loam or clay from the stone. The final products consist in part of the rounded natural sizes as dug and in part of angular crushed fragments. Cobbles of soft rotten rock unsuitable for aggregate are largely picked out by hand and wasted.

The hourly capacity of the plant is 200 tons of finished product of all sizes. Naturally, the demand does not correspond exactly to the different grades, so it is necessary to store material at times. The output of the plant is of high quality and has many uses. The greater part is used in highway construction.

Elsewhere near this plant similar material has been dug from time to time. The map shows the location of most of these abandoned workings.

The beautifully developed terraces of the Delaware River that are prominent features at several points all the way from the Delaware Water Gap to the border of Bucks County and beyond are composed of water-worn gravels and sand with occasional huge boulders. These have been dug in several places. They are similar in composition to the deposits now being worked west of Mt. Bethel. The map shows the location of two old workings close to the Martins Creek-Riverton highway.

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[34] Nordberg, Bror, Portland Sand and Gravel Co. Builds Modern Fire-Proof Plant: Rock Products, vol. 40, No. 9, pp. 43-46, Sept., 1937.

Many years ago the lower terrace gravels were worked extensively along the canal about two miles below the mouth of the Lehigh River. They were shipped by canal boat to Philadelphia and other points along the Delaware River.

Three-quarters of a mile south of Georgetown a sand and gravel pit was formerly operated in a deposit of glacial material, which consists of fine buff to yellow stratified sand overlain by five feet of red plastic boulder clay that contains pebbles and boulders of quartz, siliceous sandstone, and slate.

Alluvial sand and gravel.—Along Lehigh River alluvial deposits occur at many places, and the islands in the river also are composed of alluvial debris. In most places the alluvium consists of mud in which there is a large admixture of anthracite dust, but in a few places deposits contain much sand and gravel. Between Freemansburg and Redington the alluvial gravels have been dug for ballast in several places.

Sand from mud-dam deposits of limonite iron mines.—In the discussion of ocher a description is given of the character of the deposits in the ponds into which the waste material of the limonite mines was washed. The coarsest sand was deposited near the place where the water entered the pond, and the finer sediment was carried farther out. This sand, which consists of small grains of quartz, quartz crystals, botryoidal chalcedony, thin flakes of limonite, and a few fragments of shale, limestone, and quartzite, is mixed with considerable ochcrous clay. Even when the mines were in operation this sand was sometimes used for ordinary plaster and mortar, and since the mines were closed sand for these uses has been dug from many of the old deposits that are common throughout the region. In some places several feet of sand comparatively free from clay can be obtained, but in most places layers of clay are so closely interstratified with the sand that clean sand is hard to get. If the material were washed a large quantity of good sand could be procured from almost every mud-dam deposit in the county. Notwithstanding the difference in occurrence, the sand from the limonite mines in the limestone and that from the mines in the quartzite are strikingly similar.

In working these deposits it is usually necessary to screen the material to remove any large fragments. The annual production of this type of sand in the county formerly came mainly from a deposit one mile northeast of Hellertown. The sand was sold for 35 to 45 cents a ton at the pit, or 75 to 85 cents delivered.

Clay

Throughout the limestone regions of Northampton County there is a surface cover of residual clay composed of insoluble material derived from a great thickness of limestone which has been removed by solution. In portions of the area several thousand feet of limestone has been carried away. The amount of insoluble matter in these calcareous sediments varies but an average of 10 percent may be assumed as a fair figure. If all the residue still remained, we should have a surficial clay deposit about 300 feet deep. However, this is not the case. Seldom is the residual clay more than 20 feet deep, although in places it exceeds 100 feet; probably there is an average depth of only 10 to 12 feet. This means that most of the insoluble matter has been carried to the streams by surface erosion and transported beyond the confines of the county. Along the steeper valley slopes the limestones generally are exposed and the clay cover is present only over the flat divides.

The Pleistocene ice sheet extended through the county and probably passed over all the limestones with the exception of the two small areas bordering the Delaware River in Williams Township. The ice removed much of the surface clay, and mixed clays, sands, and cobbles from the regions to the northeast with that which remained. Therefore, the surficial clays of the county are in part residual clays formed *in situ* but generally with enough modification to justify their classification as glacial clays.

The upper one to three feet of these clays has been modified by the addition of vegetable humus so that it cannot well be used for brick. However, in some brickyards the top soil has not been removed and discarded even though it is recognized that the mixture of soil and clay affects the quality of the brick. The clay rests upon an irregular limestone surface characteristic of limestone weathering. Knobs or pinnacles of limestone may rise almost or quite to the surface in clay pits averaging ten or more feet in depth. This situation has made the use of power shovels difficult or impossible in the operation of some pits. Steam shovels have been used in some places. Of course, most of the clay pits of an earlier day were worked exclusively by hand.

In the early settlement of the region small brick yards were opened near the principal villages. In the absence of railroads, canals and good roads the product was seldom transported any considerable distance. As transportation facilities improved, most of the small plants were closed and brick were obtained from larger operations within the county or in adjoining regions.

Now there is little indication of the former manufacture of brick in several places where, according to historical records, clay pits and

brick kilns were formerly operated. It is known that there were plants in the north part of the present city of Bethlehem, along the Nazareth road between Altona and Macada, at Howertown, Weaversville, Nazareth (South Main St.), Hellertown, Glendon, Easton (College Hill), and north of Chestnut Hill. All these are now abandoned. There may have been others. Within recent years clay and brick operations have been carried on in South Easton, half a mile north of Georgetown and on the Lehigh-Northampton County line west of Bingen.

Although nearly all the clay dug in Northampton County has been used in the manufacture of brick, some of it was used at an early day for tile and pottery. In 1742 Lewis Huebner, a potter by trade, came to Bethlehem to erect a tile stove which he had made. He soon settled in Bethlehem and built a plant along Monocacy Creek a short distance north of the town. It is said that he obtained his clay from nearby pits, the exact location not known. Here he made tile stoves of various kinds. Some were almost entirely tile, others part tile and part cast iron. Some were about five feet in height. M. S. Henry gives the following description of the industry:

> Pottery, for many years carried on by Lewis Huebner, was a very lucrative trade in Bethlehem, and in 1782 that business was rated at £130. It is said that the demand could not be supplied, more particularly in years when apples were plenty. Applebutter boiling by the farmers was universal, and earthen crocks to preserve it were in great demand. Mr. Huebner also made the tiles used for stoves, as well as the common tiles for the covering of houses, barns, and stables. For barns they were in use many years, and some of them may be seen to this day. When tile could not be had, farms and stables were thatched. Pipe heads were also made by Mr. Huebner, in large quantities.[35]

Besides the uses mentioned, a small amount of clay has been used in the manufacture of portland cement by those companies that work stone containing too little alumina and silica. The plants of the Nazareth Cement Co. and Penn-Dixie No. 4 (formerly the Dexter) have occasionally had to add a small amount of the residual or glacial clay near the mills for this purpose.

Some of the clay formed in association with the limonitic iron ores of the county has attracted attention but, to the writer's knowledge, has been used only from the mud-dam deposits, if we except ocher, which is a ferruginous clay described under Mineral Pigments. In some cases the clay is white and might be suitable for various purposes. However, the occurrence in pockets of variable size surrounded by red, yellow and almost black varieties renders it impracticable to mine or dig it. In adjoining regions some of these white clay deposits have been worked on a small scale. It is doubtful whether any of these in Northampton County are of economic value.

[35] Henry, M. S., History of Lehigh Valley, p. 205, 1860.

Although the clays associated with the limonite ore are of many different kinds the following analyses are fairly characteristic. Analyses 1 and 2 were made by J. M. Stinson[36] and 3 and 4 were made by J. W. Shimer.

Analyses of clays associated with limonite ore

	1	2	3	4
Silica	53.170	49.130	72.16	64.56
Alumina	24.431	33.873	21.76	22.77
Ferric oxide	5.400	3.040	.99	5.63
Lime	.130	.120	.22	.40
Magnesia	3.376	.987	.69	1.28
Soda	1.228	.526	2.12	2.80
Potash	7.155	.634	3.02	3.25
Titanic acid	1.250	.190	....	....
Water	4.860	11.500	4.75	4.67

1. Clay found inside an orebomb, Schneider's mine, three miles southwest of Friedensville.
2. Clay from Wharton mine, two miles southeast of Hellertown.
3. White clay from Wharton mine, two miles southeast of Hellertown.
4. Yellow clay from Wharton mine, two miles southeast of Hellertown.

The residual limestone and glacial clays produce a fair quality of ordinary red brick used in various kinds of construction. Several grades of brick have been manufactured by different treatment of the clay, especially the duration and temperature of the burning process.

The Zehnder Brick Co. has been working a clay deposit in South Easton for several years. It is mainly a residual limestone clay containing pieces of quartz and flint and fragments of limonite iron ore. On a recent visit to the quarry the writer found a fine specimen of bombshell ore about ten inches in diameter such as were fairly common in some of the formerly-worked iron ore deposits. Some of the sericite from the impure dolomitic limestones is distinctly noticeable. Throughout the deposit, which has been worked to the depth of fifty feet, there are occasional glacial boulders of sandstone and quartzite that have come from regions beyond the Delaware Water Gap. These range in size up to three feet in diameter. Nearly all are within ten feet of the surface but a few are reported to have been near the bottom of the pit, thus indicating the depth to which the disturbance and reworking by the glacial ice extended.

The material is excavated by a drag line bucket. The company has three Dutch kilns with a capacity of 300,000 bricks each. At times thirteen kilns of brick have been burned annually but in recent years the production has been much less owing to the stagnation in the building industry. In certain years only 500,000 to 600,000 brick have been produced.

[36] Pennsylvania Second Geol. Survey, Rept. MM, p. 268, 1879.

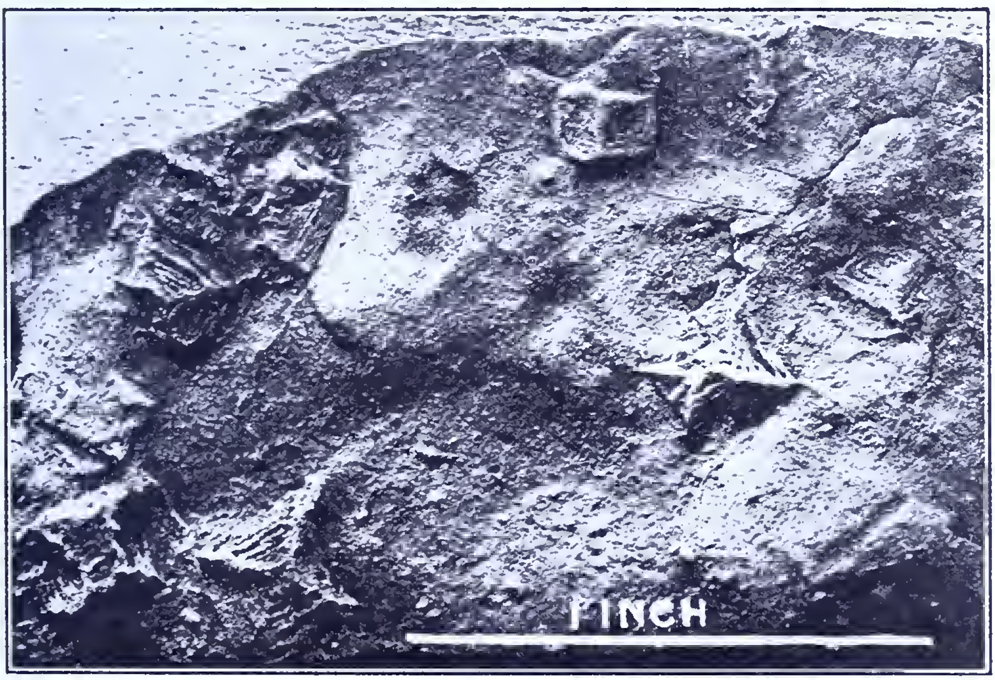
PLATE 28.

A. Illinoian till excavated by drag-line bucket. Pit of Zehnder Brick Co., South Easton.

B. Digging Illinoian glacial till for brick clay, Bingen.

PLATE 29.

A. Peat deposit near Quaker Hill.



B. Casts of halite in Beekmantown limestone, Portland.

Photo. by Lawrence Whitcomb

The brick are or good grade for ordinary construction. They are deep red and fairly porous.

The Nazareth Face Brick Co. (formerly the Nonpareil Brick and Clay Co.) operates a plant about half a mile north of Georgetown. The clay used is of glacial origin, partly sorted by glacial water. Stratification is apparent in parts of the deposit. The clay is light yellow. Lenses of sand, and quartz and slate pebbles occur in places. Occasional glacial boulders of sandstone or quartzite up to two feet in diameter are also met. Probably these were transported by floating ice and dropped as the ice melted. The entire deposit occupies a depression in the former limestone surface. Limestones crop out on all sides within short distances. The deposit seems to be only about one-fourth mile in diameter. The greatest thickness known is 60 feet but no more than 30 feet has been worked. In 1938 the working face is 20 feet high.

The clay is dug by a steam shovel and loaded into cars which are hauled up an incline by cable to the mill. Some of the largest boulders and cobbles are discarded in the pit. Formerly all the cobbles and pebbles not removed by hand were ground in a Chilian mill along with the clay, and the finished brick showed numerous rock particles. If all the rock fragments were siliceous the quality of the brick might not be adversely affected to any material extent. But mixed with this type of material were occasional pebbles of calcareous rock from the Jacksonburg or Beekmantown formations, both of which crop out in the near vicinity. These were detrimental because in the burning process they were calcined to lime with the elimination of carbon dioxide.

A sample of the clay was analyzed on Sept. 11, 1925, by the Allentown General Testing Laboratory with the following results:

				Combined oxides	
Moisture	19.45	Fe and Al	13.53	$CaCO_3$	2.14
Loss on ignition	26.10	Fe oxides	11.88	MgO	0.88
SiO_2	58.24	Al_2O_3	1.65	$MgCO_3$	1.65
		CaO	1.20		

The present practice is to get rid of all the rock particles larger than a pin head. The first step in the process is to dump the clay from the cars into a revolving screen which rejects all sizes in excess of three-eighths inch. The clay with the fine pebbles is then passed through a clay-batting machine. Paddles attached to an axle rotating at 1,850 revolutions per minute throw the hard rock particles farther than the clay pellets and effect a fairly definite separation. The clay is further treated by being passed over vibrating belt screens highly heated by electric current to dry the clay and prevent clogging. The final clay product is practically free from all foreign matter.

The clay mixed with water and passed through a pug mill is forced through the orifice by a screw and cut on the belt by eighteen wires. Waste heat from the kilns is used in the drying sheds where the brick remain two days before being put in the kilns. The burning requires seven days.

The company has eight down-draft kilns, two rectangular and six of the bee-hive type. Each has a capacity of 80,000 brick. Gas coal from western Pennsylvania and West Virginia is used for fuel. The annual capacity of the plant is 10,000,000 brick but in 1937, owing to the depression, only 4,000,000 were made.

Several different colors of brick are produced. Most of the material is sold for facing brick. The brick is used locally and also shipped to points within a radius of about 70 miles.

The other brick company working in Northampton County is the Saucon Valley Brick Co. about half a mile west of Bingen. Brick has been made at this place at intervals over several decades. In Beers' "Atlas of Northampton County" published in 1874 a brick yard is shown in the same place where the present one is located.

Some years ago a new plant was built. For several years the material used was the clay from the mud-dam deposits from the Bahl limonitic iron ore mine to the north. The deposit on the south side of Saucon Creek was used first. On its exhaustion the clay was brought from a similar deposit on the north side.

The material in the Bingen mud-dam deposits was more uniform and less sandy than that of most of the other mud-dam deposits of the region, although the section exposed in the pit showed strata of somewhat different composition. The entire thickness of the deposit was dug, and when thoroughly mixed the clay was very tough. The composition of the clay was unlike that of most brick clays, as it was a mixture of ocher, red, white, blue, and black clays, shaly fragments of limonite ore, and some grains of quartz sand, all of which were washed from the limonite ore in the log washers. The prevailing opinion among iron-mine operators that such clays are useless seems to have been disproved at this plant as brick of fair quality were successfully made here for many years. They were much more porous than the brick made from the glacial clays described above and consequently were poorly adapted for outside use but entirely satisfactory for inner walls. Their porosity caused them to absorb water and disintegrate under the action of frost.

In recent years the plant uses the residual and glacial clay obtained about one-quarter mile northwest of the plant and close to the abandoned Bahl iron mine. The thickness of the clay is variable. The face being worked in 1938 is 15 to 18 feet high.

The material is a compact residual clay, well adapted for the manufacture of ordinary brick. Unfortunately, it contains many siliceous fragments of various sizes, the residue from the limestones removed by erosion, mainly flint and chert, and numerous glacial pebbles, cobbles and boulders.

The clay is dug by steam shovel and hauled by truck to the plant. It is dumped into a hopper with bars across the bottom to collect the cobbles, which are picked out by hand. The clay then passes by belt conveyor to rolls so set that the pebbles are thrown out. It then passes through smooth rolls that crush the finer stone particles remaining. The clay goes by belt to storage and thence to the pug mill.

The brick are dried by waste heat from the kilns, remaining in the drying sheds about thirty hours. The burning is done in four kilns of 100,000 brick capacity each. Soft coal is used for fuel. About a week is required for burning. When working fully, each of the kilns is filled and burned once a month.

The brick are satisfactory for most structural work although they do contain numerous small rock particles.

Abrasives

Prior to 1912 when the Lehigh & New England R. R. extended its lines through the Lehigh Gap to the anthracite fields, a barber named Charles Semmel had purchased seven acres of land near the Gap for $50.00, from which he had dug a small amount of Martinsburg slate for razor hones. His practice was to take a few blocks of slate at a time to his shop, where during his leisure time he cut out pieces the conventional size of a razor hone. Some of these he used himself and others he peddled to the barbers of the Lehigh Valley.

The railroad crossed the Semmel property and took two acres of the land but not that part where Semmel had obtained stone for hones. The railroad officials were unable to agree with Semmel as to the amount of damage done to the property, and a board of viewers was appointed. Before this board, testimony was offered by a slate operator of Slatington to the effect that the property was an extremely valuable one and that it had been damaged to the extent of $250,000. The viewers agreed that $500 was the extent of the damage. The case came before the District Court in 1913, where it was bitterly contested and an award of $8,000 was fixed by the jury. The large sum agreed upon was evidently due to sympathy for an individual when opposed by a corporation.

The writer in assisting the railroad made a detailed examination of the material used by the barber. The slate beds worked were close to sandstone layers and therefore somewhat shielded from the compres-

sive forces and less metamorphosed. Slaty cleavage was almost entirely absent.

Under the microscope the stone was found to be composed primarily of fine sub-angular grains of quartz in a matrix of sericite. It contained minor amounts of rutile needles, calcite, pyrite and carbonaceous matter, and in some specimens chlorite, magnetite and epidote.

Testimony was offered as to the quality of the hones, several barbers expressing appreciation of them. Undoubtedly the material possesses the requisite properties for a stone abrasive in that it contains grains of quartz, which are harder than steel tools, and these are held in a soft matrix that wears away readily and frees the cutting grains before they become smoothed and polished.

Stone of this sort is abundant in the upper member of the Martinsburg of Northampton County. The market for this type of abrasive probably is small.

Peat

Although the ice sheet extended over a considerable part of Northampton County, the glacial debris almost everywhere is thin, except in the extreme northeastern corner, east and northeast of Bangor. In general there was no serious interference with drainage and comparatively few swamps or marshes were formed. In the undrained glaciated regions of the northeastern part of the United States it is common to find deposits of peat, and in some localities they have been worked.

The only place in Northampton County where peat is known to have been investigated is on the north side of Camels Hump. The glacial debris that dammed Monocacy Creek produced a shallow pond which was gradually filled with a growth of vegetable matter, consisting largely of sedges and grasses. It is known as the Detweiler peat deposit and first attracted attention about 1845, when during a dry summer it was ignited and burned for several months. It was investigated about 1903 with the intention of using the material as a nonconductor for heat in the manufacture of refrigerators, and possibly for fuel. In the refrigerators the space between the exterior wooden box and the lining of galvanized iron or porcelain was to be filled with peat.

The deposit covers about two acres on the south side of Monocacy Creek, which at this place flows in a westerly direction. A small stream, fed mainly by the Camels Hump spring, flows westward through the deposit and joins the Monocacy.

The following section shows the character of the deposit near the south side of the area.

Section of Detweiler peat deposit, three miles north of Bethlehem, Pa.

	Ft.	in.
Peat varying in color from dark brown at the top to black at the bottom	4	7
Water-deposited clay	1	2
Glacial till	—	10
Decomposed gneiss and limestone		

In the northern part of the area the underlying rock is Ordovician limestone of Beekmantown age.

Analyses of two samples each from the top (1 and 2), middle (3 and 4), and bottom (5 and 6) of the peat layer gave the following results:

Analyses of peat from Detweiler deposit near Bethlehem, Pa.

[J. T. CALLAGHAN, JR., Analyst]

	1	2	3	4	5	6
Moisture	12.06	12.37	14.74	10.31	10.06	9.82
Volatile matter	47.31	46.93	44.74	50.13	37.65	38.64
Fixed carbon	25.17	25.46	25.70	23.79	29.45	28.47
Ash	15.46	15.24	14.82	15.67	22.84	23.07

The high ash content of samples five and six is caused by the clay mixed with the samples.

The peat ignited readily and burned for a few minutes with a flame and later with a dull glow. In the first stages of burning it produced a disagreeable odor.

GROUND WATER RESOURCES

By Benjamin L. Miller and Carl A. Warmkessel*

Ground water has been utilized in all parts of the county, and yet complete data in regard to its development are not obtainable on account of the long time since the region was first settled. Many of the wells were dug more than 100 years ago, and the present owners or occupants of the land can furnish no information in regard to their depth or material penetrated.

Of the water that falls on the region in the form of rain or snow, part is evaporated, part runs off into the streams at once, and part sinks into the soil. The relative proportion of these three quantities depends upon so many factors, such as the way in which the precipitation occurs, whether in heavy downpours or gentle rain, the temperature at the time of the precipitation, the character of the ground—whether bare or covered with vegetation, whether soft or frozen, whether dry or saturated with water and the slope of the surface, that it is impossible to determine how much of the rainfall disappears into the earth to form the underground water.

Throughout the great limestone belt of Northampton County where the slopes are gentle, the soil loose through cultivation, and the underlying rocks porous or cavernous, doubtless half or more than half of the annual precipitation finds its way into the underlying rocks. In many places in this belt sink holes are well developed and there is no surface run-off. In the regions of shales and gneisses, on the other hand, where the rocks are less soluble, the slopes steeper, and the country less cultivated, the direct run-off probably exceeds the quantity of water passing into the earth.

Part of the water that passes into the ground is drawn to the surface later by capillarity and is evaporated, part is discharged by vegetation, part emerges along the slopes of the hills as seeps or springs, part probably continues its passage to the Delaware River or even to the ocean by underground channels, and part remains practically stagnant in the rocks. Though some of the deep-seated waters may originate a short distance beyond the confines of the county, it is doubtful whether any large quantity of even the deepest waters has come from distant points. The rainfall of the region thus determines the quantity of underground water available.

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* Note: The water resources of the region have been previously discussed briefly in the following publications which in part supplement the descriptions given here.
1. Hall, George M., Ground Water in Southeastern Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. W2, 1934.
2. Water Resources Inventory Report of Water Supply Commission of Pennsylvania, Part VI, 1920.

There is scarcely a rural home, a community or an industrial plant in the county that has not at one time or another been concerned with the question of ground water. Resident geologists are more frequently consulted on this problem than on any other subject in their domain and the manipulators of the divining rod, usually the forked stick, have found abundant opportunity to practice their profession. It is not uncommon for both geologists and "water witches" to be consulted on the same project. Residents of the region share the common belief in the greater purity of underground water as compared with surface stream water, a belief that in many portions of the region is well justified because of serious pollution of the streams. Treated stream water by many is used by necessity rather than by choice.

The discussion of the underground water resources of the county is best treated by sections because of the different classes of rocks in different portions. The quality and quantity of water obtainable in each section is largely determined by the kind of rocks in which the water is contained.

The underground water of the region is the source of both well and spring water. In some sections springs are abundant and supply the residents with sufficient water for all purposes. In other sections there are no springs. In a few places difficulties have been experienced in securing well water and the necessary water is obtained from cisterns. In protracted droughts water is hauled in barrels from nearby creeks or wells.

KITTATINNY (BLUE) MOUNTAIN

Inasmuch as there are no residences on Kittatinny (Blue) Mountain there has been no necessity for investigating the underground water resources of that section. However, the time may come when homes may be established there. Beyond the limits of Northampton County some houses have been built at and near the crest of this mountain.

As shown on map, the mountain is composed of the Shawangunk sandstones and conglomerates. Although these are generally well cemented by silica that fills most of the interstices, there are some fairly pervious beds, besides which the openings between the beds and also numerous joints afford easy circulation of water. Where the crest of the mountain is narrow the water level probably is very deep and only a small supply of water could be obtained except by drilling almost, if not quite, as low as the slate area at the base of the mountain. Where the mountain top is broad a small amount of water might be got by a comparatively shallow well, perhaps enough for household purposes.

Drilling in the Shawangunk is expensive as the rocks are extremely hard where they are not decomposed by weathering. A local well driller in an adjoining county failed to realize this condition to his sorrow when he took a contract to drill for water in this formation.

Springs occur along the foot of the mountain but they are generally concealed by thick talus deposits and their presence is determined by marshy conditions or by seepages when excavations are made in the talus. One of the unusual springs is far up the south side of the mountain at Smith Gap.

Because of the relatively insoluble character of the Shawangunk rocks, any water obtained from them is low in mineral matter.

MARTINSBURG SLATE REGION

The slates of the northern part of the county permit the rain water to pass quickly through the surficial soil and weathered slate but very slowly through the compact, fresh, fine-grained rock beneath. Percolation through the slate itself does take place but most of the water that goes far below the surface moves through openings of joints and along loose bedding planes and possibly along cleavage planes. These openings are very narrow and are not widened by solution, as in the limestone region, because of the relative insolubility of the slate. The result is a very slow downward movement of the rain water and the almost complete absence of large underground streams. Where faults are present the water tends to follow them.

The water from the Martinsburg is almost everywhere of good quality if not contaminated by surface pollution. However, there are several places where both spring and well waters have enough sulphur to make the water undesirable or useless. Some springs east of Seemsville contain enough to be noticeable and one well drilled northwest of Belfast contained so much that the well was abandoned. The sulphur in the water is derived from pyrite, which in some places occurs in the slates in considerable abundance. In the slate quarries cubes of pyrite are frequently noted, especially in the more highly carbonaceous beds.

The conditions in the Martinsburg favor the issuance of water from the slopes as springs and militate against large supplies of water being obtained from wells. Springs are more abundant in the Martinsburg slate belt than in any other part of the county. Springs occur in almost every valley in the region, both large and small. Northward-flowing streams have fewer springs. If the water does not emerge in a well-defined spring it may issue in a line of seepage. Some farmers dig a catchment basin in a seepage area and obtain sufficient water for household and farm purposes.

The first intention was to locate all the springs on the county map but this proved impracticable. The greater number shown in certain places does not mean that they are more abundant there but only that more of them have been located in those areas. Most of the important springs are shown in the vicinity of Kreidersville and Seemsville.

In general the springs of the Martinsburg belt do not furnish a large supply of water but generally enough for farm uses. Many of them are permanent and can be depended upon at all times, but many more flow only during the winter and spring. During prolonged droughts some disappear. Others cease to flow for no obvious reason but probably owing to the blockage of the channels or the opening elsewhere of easier passage. The permanence of these springs accounts for so few of the streams of the region becoming dry during the late summer and early fall.

The temperature of the water issuing from the springs is sufficiently high even during the extremes of winter to prevent freezing. During the winter of 1937-1938 several springs were examined at intervals. Most of them remained at 51° F.; a few changed from 53° F. to 47° F. during cold periods.

The Northampton County Home one and one-half miles west of Nazareth, was until recently supplied with water from several strong springs that issue from the slate half a mile north of the buildings. This water has now been condemned and the institution is supplied by the Blue Mountain Water Co. The spring water is available in case of an emergency. It is collected in a reservoir and piped to the buildings. The water-works were built in 1875. A famous spring a short distance from the old Nazareth Hall in the west part of Nazareth supplied the town for nearly a century. These large springs evidently reach the surface along well-defined fissures which were produced by earth movements and probably extend to great depths. The water rises under artesian pressure.

Even though springs are abundant in the slate region, they cannot supply all the residents, and wells must furnish much of the water needed. Hundreds of wells have been dug or drilled. Most of them are less than 100 feet deep. Many wells only twenty feet deep furnish enough water for farm use. Near Dannersville the wells range in depth from twenty to sixty feet. In general it is necessary to go deeper on the uplands close to the deep narrow valleys than farther back on the divides. Wells yield a fairly steady supply of water but not in large quantity. The water comes in slowly. One concern desiring a large supply, dug several shallow wells of large diameter.

All the old wells were dug by hand but almost all those put down during the past twenty years are drilled wells. These are generally

deeper, many average over 200 feet in depth. These deeper ones are apt to secure water under artesian pressure that will rise far above the place encountered and in some instances will flow.

About four miles north of Nazareth a 600-foot well drilled in the slate obtained a strong flow of water that rose to the surface. The drill probably broke into an open fissure caused by some displacement of the rocks, through which the water flowed in large volume. Other wells sunk to equal depths in the same vicinity might obtain only small amounts of water that would not rise to the surface.

LIMESTONE REGIONS

In those portions of Northampton County underlain by the Cambrian and Ordovician limestones the water problem is serious in many cases.

Ground water in limestone regions flows mainly in well-defined open channels formed by solution along ordinary joints or bedding planes, and the surface water passes into these underground channels. With the exception of Hokendauqua, Catasauqua, Monocacy and Bushkill creeks, which head in the slate region, surface streams are practically absent in the limestone belt north of the Lehigh River. Count Zinzendorf in a letter dated March 15, 1743, described the region between Bethlehem and Nazareth as "absolutely a desert without wood or water, and of such a nature that it never can be sold." Another writer[37] in 1799 said that "part of the road (between Bethlehem and Nazareth) runs through a tract of land, which is exclusively called the Dry Land, on account of its want of any creeks, rivulets, or springs above ground. It is, however, well settled; the inhabitants bring water for common use from the nearest spring or brook. This is often at the distance of one, and even two and three miles. Of late, however, prudent and able settlers have begun to dig wells, whereby the value of their lands is considerably enhanced."

As the water in the limestones is concentrated in definite channels, one of these channels must be struck to obtain water in quantity, and the uncertainty of finding one of them has favored "water witching," which is still practiced in many regions, although repeatedly shown to have no scientific basis and to be entirely unreliable.

Some water is usually obtained at the contact between the loose residual and glacial loamy clay and the underlying compact limestone. Many wells fifteen to thirty feet deep draw their supply from this horizon and obtain sufficient water for domestic use except in times of drought. The water in such wells is, however, easily polluted

[37] Ogden, J. C., Excursion into Bethlehem and Nazareth in 1799, pp. 41-42, Philadelphia, 1805.

by surface drainage, and these wells are gradually being abandoned. In place of the abandoned shallow wells deep wells are sunk; if these are not successful, cisterns are used. Between Butztown and Tatamy probably more than half of the farmers depend on cistern water for household use, and cisterns are also extensively used in other sections of the limestone areas except along permanent streams.

Many deep wells have been bored in the limestones during the last few years, and most of them have been successful. One experienced driller states that he has obtained fair supplies of water at depths of about 200 feet in about 70 percent of the wells he drilled in the limestones of this section. As shown in the table, some wells procure very large supplies, a few of them from several different horizons, yet a hole may be sunk within a few feet of a strong well and still be dry on account of the impervious character of the solid limestone. For this reason dry wells before being abandoned should be dynamited in order to shatter the surrounding rocks. As the rocks have been greatly broken by folding and faulting, water may be obtained more readily from these limestones than from those in other regions that have been less subjected to stresses.

The water in most of the deep wells rises above the level at which it is struck, and it overflows from numerous wells. In general the deep wells obtain water under the greatest pressure, but, due to marked irregularity, locations where flowing wells can be obtained cannot be predicted.

Many springs occur in the limestone areas. Some of them are unusually strong, being underground streams that rise to the surface under artesian pressure. Some of them have been important sources of municipal water supply. The spring at Bethlehem that supplied the borough with water for nearly 170 years furnished more than 800 gallons a minute. Christian Spring, two miles west of Nazareth, is also well known. A large spring that emerges near Monocacy Creek one and one-quarter miles south of Hanoverville may be part of the creek which follows an underground course for a few miles instead of following the great bend of the creek past Brodhead. Lost Cave, half a mile northeast of Hellertown, contains a stream of water that probably comes to the surface as seepage in low marshy land a short distance away. Numerous smaller springs in many places are drawn upon by the inhabitants of the region, and also furnish much water to the surface streams, many of which, such as the small stream that passes through Butztown and Middletown, are almost entirely dependent upon springs.

All the springs of the limestone region are affected by drought, and many disappear in summer, though the larger ones have never been known to fail entirely.

All the ground water of the limestone areas is hard because of the mineral matter it dissolves in passing through the soluble rocks. The amount of material in solution ranges within wide limits owing to the differences in distance through which the water has flowed, the length of time it has remained in contact with the rocks, and the relative solubility of the inclosing limestones. This water causes the formation of much scale in boilers. In drinking water the mineral matter, mainly calcium and magnesium bicarbonates, is not regarded as detrimental. Analyses on a later page show the composition of limestone water.

The limestone waters are subject to contamination, as the areas are thickly settled and surface waters in many places find ready access to underground channels. Limestone waters near cities and towns, whether from wells or from springs, should be treated on account of the sewage that is continually poured into the underground channels, and should be examined bacteriologically from time to time to ascertain the extent of contamination. If wells are tightly cased for some distance into the solid rock the danger of surface contamination is lessened, but it is not entirely removed, as polluted waters may reach great depths through open fissures with practically no filtration. Doubtless a complete sanitary survey of the region would demonstrate that many of the sources are too badly polluted for safe use.

There are many examples of unusual occurrences of ground water in the limestones of the region. Some years ago the Nazareth Cement Co. in search of a water supply was advised to drill in the northwest part of its property. After many difficulties the hole was extended to 817 feet and only a small amount of water obtained. The hole was started in the Jacksonburg limestone but at 240 feet entered Beekmantown dolomite with some beds of low magnesian rock and continued in this formation. The senior author was consulted and in 1925 a new location was suggested in the low ground southeast of the plant where there were some sink holes. The drilling here was stopped at 125 feet and pipe put in the well to the depth of 102 feet. This well continues to furnish a large supply of water, as does another similar well drilled later in the same field.

By experience it has been found that the best surface indications of underground streams in the limestone of this region are sink holes into which the surface water flows to unite with underground streams. Boring in the vicinity of sink holes or in the line of a series of sink holes is reasonably certain to encounter water. In some places the water is present in enormous quantities. Surface depressions that are not entirely closed are also favorable indications. Large supplies of

ground water can generally be obtained in the vicinity of limonite iron ore mines or deposits. Scarcely an iron mine in the entire region was worked to a depth of fifty feet without encountering water and at greater depths the amount became so great as to cause certain mines to be abandoned. There is a close connection between the iron ores and ground water in that the ore deposits were concentrated and deposited in those places where there was free circulation of ground water. The same sort of circulation and ore formation still continues.

In certain places the limestones have been unduly shattered as a result of complex folding and faulting. If such places can be located for drilling sites abundant water can be assured. Drilling is difficult in such places as the hole is apt to become crooked and the drill may stick.

In these limestone regions both north of the Lehigh River and in Saucon Valley there is no recognized aquifer. Even though there were some bed or series of beds with greater permeability so that the water would be yielded more readily, the complexity of structure would prevent one from predicting the depth at which it would be encountered.

From what precedes it also should occasion no surprise when one well or several obtain plenty of water at 100 to 200 feet and on an adjoining property a well twice as deep furnishes little water.

The numerous veins of calcite and quartz in the various limestones, particularly noticeable in the Jacksonburg cement rock, furnish abundant evidence of the free circulation of ground water through these rocks in past geologic ages.

In the limestone areas, well drillers frequently encounter cavities where the drill drops a few feet. These are underground solution caverns. Some of these cavities are filled with sand and gravel that has come from the surface.

In northeast Catasauqua almost on the county line, the borough of Catasauqua drilled two holes, one 212 feet deep, in clay, sand, gravel and iron ore, without striking bedrock. Dolomitic limestone outcrops only a short distance away, so it seems that a deep solution pocket was encountered. A short distance east of Green Pond there is a similar occurrence, although there the fine silt was penetrated only 100 feet.

The deep limestone wells at Illicks Mill along Monocacy Creek, a mile north of Bethlehem, are 700, 750 and 1,013 feet deep respectively. These are a part of the City of Bethlehem water supply. They have a natural flow but are vigorously pumped to yield a much greater supply.

CAMBRIAN SANDSTONES

The band of sandstones and quartzites along the sides of the South Mountain has been prospected for water in few places, mainly on account of the narrowness of its outcrop. The quantity of water encountered in the operation of the limonite iron mines in this belt of rocks south of Easton and in the narrow valley one and one-half miles southeast of Hellertown proves that these sandstones and quartzites contain much water. The water passes along joints and bedding planes or through the rocks themselves and is seldom concentrated in definite streams, except in places where the rocks have been broken and displaced by earth movements. The best place to procure water is at the contact between these rocks and the underlying gneisses.

Wells in these rocks should be sunk a short distance away from where they disappear beneath the limestones. As the rocks near the mountain almost invariably dip steeply, the sandstones or quartzites are within a short distance carried beyond the depth at which they are available as sources of water. Springs are not numerous in these rocks, but there are some in places where the rocks have been shattered.

The water from the Cambrian quartzites and sandstones is low in mineral content because of the insoluble character of the rocks with which it comes into contact, and it is uncontaminated because the slopes of the mountain are sparsely settled.

PRE-CAMBRIAN GNEISSES

Pre-Cambrian gneisses form the mountains in the southern half of the county. These regions are thinly settled on account of the steep slopes and the stony character of the soils, which are only locally suitable for cultivation. The rocks near the surface are greatly jointed and permit the entrance of water. As the depth increases the joint spaces become narrower and consequently the water moves more slowly. Lines of seeps or springs furnish most of the residents of the region with ample supplies of water. Wells ten to twenty-five feet deep yield fair supplies.

Half of the deep wells that have been bored have been failures. If water is not obtained within 200 feet it is generally regarded as useless to continue to lower levels. A few excellent wells have been obtained in the gneisses but most of them yield only small quantities.

The water in the gneiss contains little dissolved mineral matter, and when it is protected from local pollution it is very desirable. In a few places where pyrite is an abundant constituent of the gneisses the water may contain iron.

As has been described in the chapter on structure, and as shown on the map, some of the masses of gneiss are bounded by faults. These faults are generally near the base of the mountain and are marked by seepages and springs. Wells near these faults should obtain ample supplies of good water. On the north side of Camels Hump there is a spring of excellent water that for many years was bottled and sold locally. This spring is along the fault that brings Byram gneiss in contact with Beekmantown limestone. There were other springs and seepages nearby but these have disappeared since the opening of the quarry of the National Portland Cement Co. and the vigorous pumping that has been done there.

Springs occur also in the gneiss areas away from the fault contacts with Paleozoic rocks. Some of these are far up on the slopes, even near the summits. Probably all of these are along faults also, although this is not known definitely. Springs of this character on the south side of Poke Valley Run supply Hellertown with an excellent quality of water. Three springs high on the mountain back of Lehigh University issue from gneiss and produce a small stream (now covered over) that passes through the campus. Other cases of the same sort could be cited.

The senior author has been asked about the probability of obtaining water from wells on the crest of some of the gneiss hills inasmuch as "water witches" have stated that good supplies could be obtained. The chances of getting more than that coming from surface seepage in wet weather are remote unless a fault plane is encountered and that at considerable depth.

MUNICIPAL WATER SUPPLIES

Some of the boroughs and cities of Northampton County obtain part or all of their water from wells and springs. In some cases these have proved adequate but, with increased growth, additional supplies have been sought, and generally from streams. In 1938 Bethlehem is considering a proposition that would include the construction of a dam across Wild Creek in Carbon County and the transportation of water by a tunnel through Kittatinny (Blue) Mountain.

The important municipal water supplies of the county are discussed briefly in alphabetical order.

Bangor and Roseto.—These two boroughs are supplied with water by the Bangor Water Co. The water is obtained from wells, springs and small streams fed by springs. The water all comes from the upper member of the Martinsburg or from the glacial drift or hillside talus.

The most important springs are known as the Handelong Springs, located close to the West Fork of Martins Creek just east of the nose of the Big Offset. One located about half a mile to the south is known as the Muffley Spring and two others about 1½ miles north are the Pritchard and Betz springs.

Water is obtained from the upper portion of the West Fork and from Labar and Stofflet runs (unnamed on map) a short distance to the east.

The supply from springs and streams has been supplemented by 14 wells, 11 of which are along the foot of Kittatinny (Blue) Mountain east of the Big Offset and range in depth from 38 to 517 feet. A 268-ft. well is located on the south side of the Big Offset, a 264-ft. well in the west part of the borough and a 115-ft. well in East Bangor.

One reservoir, the Handelong, of 1,000,000 gallons capacity is near the Handelong Springs and another of 2,000,000 gallons capacity a short distance to the north.

All the water is soft because it comes from rocks containing little soluble matter.

Bath.—The borough of Bath obtains most of its water from three wells in the Martinsburg formation a short distance to the north. It seems probable that the deeper wells struck the Jacksonburg limestone, although no information is at hand to determine whether this is true. The wells are 350, 750 and 850 feet deep respectively. The first two are flowing wells during part of the year. The combined capacity of the three is about 120 gallons per minute. Springs north of the borough also contribute to the water supply.

Bethlehem.—Although part of Bethlehem lies within Lehigh County it seems desirable to describe the water supply of the entire city.

The first successful waterworks in Pennsylvania was established in 1754 at Bethlehem, when the water of a large spring on the east side of Monocacy Creek, back of the site of the present Hotel Bethlehem, was forced by means of water power developed by Monocacy Creek through wooden pipes to a tower between Community House and the Sisters' House and thence distributed throughout the borough.

An excellent account of this early development is contained in an article[38] compiled at the request of the Borough Council in 1877 from which the following paragraphs are abstracted.

[38] Rau, Robert, Historical Sketch of the Bethlehem Water Works, 1877, 10 pp.

The spring, pouring its sparkling tide from out its bed of magnesian limestone, near the banks of the "Menagassi," is today, and has been ever since the Moravian Brethren, in March of 1741, made them an humble home in the trackless forests, the source of water supply for Bethlehem. Situated at the foot of the hill, upon the declivity of which the first log cabin was erected by the zealous missionary pioneers, it doubtless determined to a great extent the location of the slowly growing settlement. Until 1754-55 the water for the use of the community was distributed by water carriers or haulers, formally delegated for the purpose; from among the names of these Aquarii, a faithful chronicler of old time events* has preserved the following: Godfrey Haberecht, who first filled the office and who was appointed in July of 1742; ——— Schnall, of whom it is recorded that in the discharge of his duties he had the mishap to upset his cart and fracture his arm; Peter Peterson whilom from Staten Island; Robert Hussey, in 1748, and after him Mattheus Wittke, the last of the incumbents.

In September of 1751, we find the name of Hans Christopher Christiansen upon the list of newly arrived settlers.

This man, subsequently proving to be so valuable an addition to the colony, was born near Hadersleben, in Holstein, then under Danish rule, was by profession a millwright and by nature a mechanical genius. To the inventive ability of this ingenius Dane it was left to devise a method of supplying the community with water from the spring, by means otherwise than distributing it by water carriers. In the Spring of 1754 Christiansen commenced the erection of the first water works. The machinery was placed in a frame building 19 by 22, a few yards east of the oil and bark mill, whither the spring water was led by a conduit into a cistern. The pump was made of lignum vitæ, the cylinder being five inches in diameter.† The water was forced through wooden pipes, up the hill into a wooden reservoir or distributing tank, built within the "little square"—the place now occupied by the Moravian church—being a perpendicular height of 70 feet. These pipes were bored hemlock logs which had been floated down the "west branch of ye delaware," as the old accounts here term the Lehigh, from Gnadenhuetten, on the Mahoning, an Indian mission, near the site of Lehighton, in Carbon County.

The arrangements were sufficiently advanced by June 20th of the same year to admit of a trial, and on that evening the water was thrown in a jet "as high as the adjoining houses." The event created great gratification in the little community, and the novelty of the enterprise invariably excited the wonder and admiration of visitors.

It is to be deplored that a more specific account of these first water works is not to be obtained, yet so much can be inferred from the succinct statements of the chroniclers above referred to, that many interruptions and disappointments were caused by the bursting of the wooden mains. There was subsequently made, but with no better result, an attempt to substitute 1¼-inch lead pipes, which were made of sheet metal, soldered along the edges and imbedded in a cement of pitch and brick dust, laid in a gutter of hard burnt brick.

Being convinced of the incompleteness of his work and the possibility of improving upon this, his first attempt, Christiansen commenced, in 1761, the construction of more powerful machinery, such as might meet the wants of the now evidently growing settlement, and this, moreover, in pursuance of a plan perfected by himself, John Arbo and ——— Marshal.

A two-story building 22 by 30 was erected for the reception of the works, a little to the south of the frame building. This house, well preserved, is still standing and bears evident traces upon its door posts and window frames of the fire which, on the 18th of November, 1763, destroyed the original oil mill, a wooden structure across the way.

* The late Rev. Wm. C. Reichel, to whose patient researches many of the following facts and figures are gratefully credited.

† According to the specific statement of Charles David Bishop, whose father, John David Bishop, was apprenticed to the Danish millwright, Hans Christopher Christiansen, and who subsequently, as well as his son David, and later, his grandson, Gilbert Bishop, had the care of the water works intrusted to him. To the kindness of Mr. Gilbert Bishop are due many important data herein stated.

After the lapse of a year, Christiansen reached the completion of his task, and on the 6th of July, 1762, the new pumps raised the water for the first time. Nor were forgotten, amid the general rejoicings of that memorable day, the authors of the achievement, for, as the record quaintly tells us, Christiansen received 30 shillings, and Christopher Demuth his assistant, 15 shillings "for ye water running."

The machinery of these second water works, which was one of the sights of the town and which never failed to interest visitors, consisted of (quoting the description of Charles D. Bishop) 3 single-acting force pumps (of iron, cast at Durham Furnace at a cost there of £8 12s. 4d.) of 4-inch calibre and 18-inch stroke, worked by a triple crank (forged by the resident blacksmith, Stephen Blum, and ever the just subject of pride as to ingenuity of workmanship) geared to the shaft of an undershot water wheel, 18 feet in diameter and two feet clear in the buckets.

The head of water was 2 feet. On the water wheel shaft was a wallower of 33 rounds, which geared into a spur wheel of 52 cogs, attached to the crank; the three piston rods were attached each to a frame or crosshead working in grooves to give them a motion parallel to the pumps. The crossheads were of wood, as also the parts containing the grooves for guides. The works were calculated to raise the water 70 feet, subsequently, however, increased to 112 feet. The rising mains were made of gum wood, as they were subject to greater pressure, the other pipes of pitch pine.

The cost of the entire works, including the tile-covered stone building, was £514 16s. 5d.

The distributing reservoir was a *stand-pipe*, a wooden tower, shingle-roofed, which was built in "the little square" already mentioned, surmounted, moreover, as sundry expense accounts inform us, with an embellishment in the way of a weather vane of piscatorial device.* From this point the water was distributed into cisterns or tanks which were built in the vicinity of the principal dwellings.

This spring continued to supply practically all the water required for the borough until 1912. A 300-foot well was then drilled between the spring and the creek, but the water was so badly contaminated by sewage that it could not be used. Water from a 390-foot well at the Bethlehem Silk Mill, half a mile farther north, was used to supplement the spring supply. The spring finally, however, became contaminated and had to be abandoned. At times it yielded 1,200,000 gallons a day, and the 390-foot well furnished 460,000 gallons a day.

In 1912 Bethlehem began to use the water from two wells at Illick's Mill, on Monocacy Creek about one and a half miles north of Bethlehem. These wells, which are 700 and 750 feet deep, overflow, but they must be pumped in order to obtain a sufficient supply. Together they yielded 2,000,000 gallons a day. A third well, 1,013 feet deep, was completed on the same property just east of the creek in March, 1915. Tests show it to have a capacity of 1,351 gallons a minute, or approximately 2,000,000 gallons a day.

* The identical vane, which, upon the old water tower, for forty years complied with the ever varying behests of the wind, and furnished to the population of the village the indications of weather changes, whether fair or foul, with untiring fidelity, was in 1856 swung over Temperance Hall on Broad Street, where, it must be admitted, it never received on the part of the neighboring dwellers, the esteem and respect which its antiquity warranted. Albeit its re-dedication was again to the honor of cold water, it is said that this symbolic device never again seemed to be in its element, and, in the dreariness of stormy nights, would creak dismally, while veering in obedience to the fitful blasts.

The water from the spring and the wells is hard. The wells are in limestone. As the limestones are cavernous and the region is thickly settled, it is necessary to watch the water carefully and to make frequent bacteriologic examinations. It is, however, seldom necessary to add liquid chlorine in large quantity.

The South Bethlehem Gas & Water Co. built works in 1865, taking water from Lehigh River. The Mountain Water Co. was chartered in 1893 to supply water in Bethlehem Township from springs on the mountain near Seidersville. The two companies united in 1894 under the name of the Bethlehem Consolidated Water Co., which sold its franchises and properties in 1903 to the Bethlehem City Water Co. The City of Bethlehem later purchased the company. It obtains its water from the two sources mentioned, and for some time furnished water to Bethlehem (South Side), Fountain Hill, Northampton Heights, Bethlehem (West Side), Rittersville, East Allentown, and the Allentown State Hospital at Rittersville. Its service is now limited to Bethlehem and Fountain Hill. Some houses still receive spring water from the side of the mountain, where Tinsley Jeter built a reservoir in 1866 near St. Luke's Hospital. Pipes were laid from this reservoir through several streets as far as Union Station. In 1872 the Cold Spring Water Co. laid pipes from springs on the side of the mountain near Delaware Avenue to a few residences on Fountain Hill.

The river water supplied to the City of Bethlehem is pumped from a dug well near the river to reservoirs on the side of the mountain above St. Luke's Hospital. In sinking the well several flows of water were obtained from the quartzite beds that were penetrated. The well was sunk under the impression that water from Lehigh River would filter through the alluvial material and fill it. The water must be filtered on account of the sewage poured into the river from the cities farther upstream. The acids from the waters of the coal mines along the upper course of the river destroy many of the bacteria, although not all.

From the plant the water is pumped into a sedimentation reservoir 420 by 220 feet and 21 feet deep, which has a capacity of 14,000,000 gallons. It then passes through six preliminary filters and six open, slow sand filters having a capacity of 4,000,000 gallons a day. The filtered-water reservoir holds 5,000,000 gallons. The filtered water can be treated with liquid chlorine when that is necessary.

The City Engineer states that 86 percent of Bethlehem's present water supply comes from the Lehigh River. In periods of extreme drought the river becomes so low and the water so seriously contaminated that another source of supply is being sought. Two propositions are under discussion although others have been con-

sidered. One is to bring stream water from Wild Creek, Carbon County and the other is to utilize the excessive water that is being pumped from the quarry of the National Portland Cement Co. a few miles north of Bethlehem.

Catasauqua.—Inasmuch as Catasauqua is mainly included within Lehigh County it seems better to omit any discussion of its water supply in this volume.

Easton.—At present the City of Easton owns the entire system supplying the city with water. Water is pumped from the Delaware River to the extent of 2,300,000 gallons every twenty-four hours. In addition two 490-foot wells about one-fourth mile north of Bushkill Park, in the Beekmantown limestone, yield 150,000 gallons daily.

South Easton is supplied with water from six 60-foot wells located close to the Lehigh River about one mile above the junction with the Delaware and one 470-foot well nearby. They are in the Allentown limestone. Together these wells yield 1,296,000 gallons a day. Some springs near the base of Morgan Hill also constitute a part of the South Easton water supply. They yield 140,000 gallons per day.

Hellertown.—For many years Hellertown obtained its entire supply of water from several fine springs on the south side of Poke Valley. The water is collected in a reservoir on the north slope of the hill and from there led through a main to the borough. The water emerging from faults in the pre-Cambrian gneiss is of excellent quality. During a drought a few years ago the supply of water was so low that an additional amount seemed desirable. Accordingly a well was drilled in the bottom of Poke Valley near an old iron mine. It was sunk in the Hardyston sandstone, most of which was thoroughly decomposed. It is 286 feet deep and has never been pumped to capacity. It has yielded 150 gallons per minute for an extended period without lowering the water level.

Nazareth, Pen Argyl and Wind Gap Boroughs.—The Blue Mountain Consolidated Water Co., which obtains its water mainly from the north side of Kittatinny (Blue) Mountain, supplies the boroughs of Nazareth, Pen Argyl and Wind Gap. The water comes partly from the Aquashicola Creek and partly from wells in the near vicinity Water is obtained also from two wells and some springs on the south side of the mountain about one mile northwest of Pen Argyl.

The company also has the abandoned Douglass slate quarry, located about 2½ miles northwest of Nazareth. This quarry is filled with water from springs. For several years it supplied Nazareth.

Northampton.—Northampton is supplied by the Clear Springs

Water Co. with water obtained from Spring Mill Creek in Lehigh County, supplemented by some pumped from the Lehigh River.

Walnutport.—The Borough of Walnutport is supplied with water from springs along the base of Kittatinny (Blue) Mountain.

Wells of Northampton County

GLACIAL TILL

Owner	*Location*	*Depth*	*Depth to water level*	*Yield gal. a min.*
The Candy Kitchen	Bangor	50		10
Weiss Coal and Lumber Co.	do.	60		10
	1¾ mi. southwest of Centerville	65		3
	Near Portland	70		6
	do.	34		3

MARTINSBURG SHALE

	Ackermanville	85		5
Bangor Water Co.	Bangor	570	100	20
do.	do.	500		250
do. (Muffly)	do.	268		
do. (Handelong Reservoir)	do.	165		
do. (Betz)	do.	150		150
do. (Stofflet)	do.	150		
do. (Joseph Handelong)	do.	244		
do. (LaBar)	do.	380		
do. (Widman)	do.	517		
do. (Betz or Pritchard)	do.	158		
do.	do.	38		
do.	do.	147		
do. (Stofflet)	do.	114		
do. (Althorfer)	do.	350		
do.	do.	80		
do. (Stand Pipe)	do.	590		
do.	East Bangor	117		½
Crow Silk Co.	do.	220		4
Wm. Bray	do.	115		10
Borough of Bath	Bath	8		50
do.	do.	600	60	65
do.	do.	500		
do.	do.	300		
do.	do.	550		
Levi Beck	Centerville	80		5
Joseph Thompson	1 mi. west of Centerville	100	8	10
	Delabole	100		3
L. Pottsman	2½ mi. north of Johnsonville	80		15
	Mount Bethel	55		6
	do.	65		6
	do.	70		6
	do.	100		6
Blue Mt. Water Co.	Pen Argyl	450	100	80
do.	do.	20		25
Joseph Shannon	do.	78		5
	1½ mi. northwest of Richmond	150		10
Blue Mt. Water Co.	Wind Gap	150		150

Owner	*Location*	*Depth*	*Depth to water level*	*Yield gal. a min.*
Lehigh & New England R. R.	Wind Gap	450	15	150
Charles Beck	do.	2658	125	30
Robert Ritter	do.	223	220	15
JACKSONBURG LIMESTONE				
Penn Dixie Portland Cement Co. No. 6	Bath	304		300
do.	do.	150		10
do.	do.	105		100
D. L. Koch	Christian Spring	90		15
School House	Martins Creek	140		20
Penn Dixie Portland Cement Co. No. 4	Nazareth	570	85	150
do.	do.	606	80	150
do.	do	200		50
do.	do.	200		200
do.	do.	250		10
J. A. Horner	do.	235		100
do.	do.	150		5
do.	do.	250		125
Lone Star Cement Co.	do.	269		20
do.	do.	150		100
do.	do.	269		5
Milton Kessler	do.	57		20
Blue Mt. Water Co.	do.	400		150
do.	do.	325		150
do.	do.	130		150
John Keppinger	Northampton	250		42
Borough of Northampton	1¼ mi. north of Northampton	300		100
do.	do.	200		——
do.	do.	200		——
Atlantic Water Co.	Stockertown	75		15
John Hendricks	do.	255	110	20
BEEKMANTOWN LIMESTONE				
Keystone Portland Cement Co.	S. W. Bath	500		300
do.	do.	175		300
Archibald Johnson	Camels Hump	304		200
George Holten	1 mi. N. E. of Catasauqua	225	55	10
Northampton Brewing Co.	Northampton	240		110
D. G. Dery Silk Mfg. Co.	do.	500		Dry
do.	do.	119		50
Lehigh Portland Cement Co.	1½ mi. S. of Martins Creek	160	60	200
do.	do.	155	60	200
ALLENTOWN LIMESTONE				
City of Bethlehem	Bethlehem	300		312
Bethlehem Silk Co.	do.	400	10	900
Gorman Bros.	do.	100	50	35
Myer Herberger Dairy	do.	171	45	150
City of Bethlehem	1 mi. N. of Bethlehem	1012		1450
do.	do.	700		800
do.	do.	750		800
Arson Mosser	½ mi. N. of Butztown	110	35	15
Borough of Easton	South Easton	80		
do.	do.	350		

Owner	*Location*	*Depth*	*Depth to water level*	*Yield gal. a min.*
Penna. Edison Co.	Easton	550	250	200
City Ice Co.	do.	250	250	200
Bushkill Park	do.	400	115	400
do.	do.	450	115	400
C. K. Williams & Co.	do.	650		450
Verle Brewery	16th St. & Bushkill, Easton	500		100
Seip Restaurant	3rd St., Easton	152		75
Seip's Brewery	Front St., Easton	125		100
Wilson Bros.	Near Old Fair Grounds, Easton	200		
do.	21st St. & Northampton St., Easton	150		60
W. H. King Dyeing Est.	Easton	89		80
Lawrence School	1½ mi. N. of Easton	211		20
S. Easton Water Co.	1½ mi. N. W. of Easton ..	450	3	500
Easton Sanitary Milk Co.	Easton	259	20	100
Moyer Dairy Co.	do.	91		50
Easton Merchants Ice Co.	do.	150		150
Wilson Arbogast	Farmersville	265	45	20±
John Rowe Dairy	2 mi. E. of Farmersville ..	200		
Northampton Country Club	1 mi. E. of Farmersville ..	260	117	150
John Rau	1½ mi. E. of Farmersville..	162		50
Robert Person	½ mi. N. of Farmersville ..	191	70	20±
William Weaver	Freemansburg	125	60	15
E. E. Workheiser	do.	82		30
do.	do.	102		
H. S. Snyder	Green Pond	350		Dry
do.	do.	125		50
John West	¼ mi. S. E. of Middletown	139	90	50
do.	do.	235		200
do.	1 mi. E. of Wagnertown ..	175		
TOMSTOWN LIMESTONE				
Bethlehem Steel Co.	Coke Plant, Bethlehem	353		10
do.	do.	150		10
do.	do.	565		550
do.	do.	659		1170
do.	Bethlehem	773		700
South Bethlehem Brewing Co.	do.	163	54	100
Lehigh Steam Laundry	do.	189		100
Lehigh Valley Cold Storage Co.	do.	425		200
John Nagy	Freemansburg	88	85	30
Kutz	do.	126	120	20
John Weaver	North Hellertown	150	45	100
Emma Lerch	½ mi. S. E. of Redington ..	262		Dry
do.	do. ..	180		20
Ted Meyers	West side of Monocacy Creek	117		25
HARDYSTON SANDSTONE				
Hellertown Water Commissioners	Hellertown	286		150†
Robert Felker	Seidersville	208	90	15
PRE-CAMBRIAN GNEISS				
John Ruth	2 mi. N. E. of Easton	50	25	15
John Rutz	do.	928	30	30

Springs

Owner	*Location*	*Temperature, ° F.*	*Flow gal. a min.*
W. C. Weiss	Across stream from Santee Mill	50	—
A. Johnson Farm		51	—
A. Flory	Bath-Nazareth Pike	47½	25
	North of Bath Pike, west of Shoenersville Pike junction	44	5
	Farther up field	45	7
H. Fehnel	2 mi. N.-N. W. of Jacksonville	No. 1. 47	35
		No. 2. 44	12
		No. 3. 45	25
H. Fehnel	100 yds. north of above	48	10
N. Cessanie	Howertown	44	50
E. C. Fehr	Weaversville Hotel	49	15
H. Newhard	1 mi. N. of Howertown	48	12
M. M. Laubach	2 mi. N. W. of Howertown	52	10
Lapowinza Fish & Game Club	1 mi. S. of Kreidersville on Hokendauqua Creek	50	5
	S. E. side of Morgan Hill	54	3
	Poplar Spring Inn	53	10
	Rear of Deemer School	54	2
	¾ mi. E. of Mt. Pleasant School	53	10
	1 mi. S. of Fairview School	53	8

Analyses of well and spring waters of Northampton County

(Parts per million)

Constituents	1	2	3	4	5	6	7	8	9	10	11	12	13	14 and 15	16	17	18
SiO_2	—	3.8	30	—	11	11	—	1	17	11	26	16	28	8.4	7.8	6.3	7.4
Fe_2O_3	—	.14	.19	—	.06	.03	—	3	.07	.19	.74	.08	.23	.06	1.2	.7	2.4
Al_2O_3	—	—	—	—	—	—	—		—	—	—	—	—	—			
Ca	—	18	62	—	51	5.7	—	48	54	93	56	30	27	18	130	26.7	49.6
Mg	—	3.1	17	—	33	2.2	—	29	28	52	8.4	18	7.9	6.0	12.4	18.5	25.0
Na	—	1.4	4.2	—	9.8	1.3	—	14	2.4	38	9.0	4.7	3.6	4.9	—	—	—
K	—	.7	2.1	—	2.2	.6	—		1.9	7.7	2.7	4.0	1.8	2.4	—	—	—
CO_3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
HCO_3	—	60	194	—	242	24	—	245	191	359	105	137	74	61	—	—	—
SO_4	—	7.7	50	—	30	4.7	—	35	71	95	70	5.0	44	30	31.0	6.9	47.6
Cl	1.2	1.5	11	3.4	19	1.0	4.5	21	8.5	58	24	8.0	1.8	2.2	—	—	—
NO_3	—	1.5	12	.12	31	.27	—	—	3.6	73	.91	40	.10	.0	—	—	—
Organic and Volatile Matter	2.4	—	—	34	—	—	15	2	—	—	—	—	—	—	116.0	85	168
Total Solids	40	70	287	150	300	35	71	274	278	609	261	172	150	112	440.4	213	525.2
Total Hardness as $CaCO_3$	13	58	225	—	263	23	—	—	250	446	174	149	100	70	—	—	—

1. Camels Hump Springs on north slope of Quaker Hill. Water from pre-Cambrian gneiss. Analysis by W. H. Chandler.
2. Springs at Bangor, owned by Bangor Water Co. Glacial drift. Analysis by Margaret D. Foster.
3. Spring at Easton owned by C. K. Williams & Co. Serpentine. Analysis by Margaret D. Foster.
4. Mountain Spring Beverage and Water Co., Easton. Analysis by James H. DeLong.
5. Spring 1 mile northwest of Easton owned by Mrs. Leona Johnson. Beekmantown limestone. Analysis by Margaret D. Foster.
6. Well at Bangor. Martinsburg shale; 500 feet. Analysis by Margaret D. Foster.
7. Well near Bath, 225 feet. Analysis by S. P. Sadtler.
8. Well of Bethlehem Silk Mills, 290 feet, limestone.
9. Well 1 mile north of Bethlehem, 1,012 feet. Allentown limestone. Analysis by Margaret D. Foster.
10. Well at Easton, 91 feet, limestone. Analysis by Margaret D. Foster.
11. Well 2 miles northeast of Easton, 50 feet. Pre-Cambrian gneiss. Analysis by Margaret D. Foster.
12. Well at Green Pond, 125 feet, Allentown limestone. Analysis by Margaret D. Foster.
13. Well at Nazareth, 400 feet. Jacksonburg limestone. Analysis by Margaret D. Foster.
14. & 15. Two wells at Nazareth, 130 and 325 feet, Jacksonburg limestone. Analysis by Margaret D. Foster.
16. P. S. Trumbower farm, Nazareth, 125 feet.
17. Mann Farm, Nazareth, 192 feet.
18. Northeast of new quarry of Nazareth Cement Co., 200 feet.

The soils of Northampton County constitute its most valuable mineral asset. Although manufacturing industries generally receive major attention, agriculture contributes largely to the welfare of all the residents.

As the kind of soil usually is very closely connected with the character of the underlying rock, a geologic map may indicate fairly well the distribution of the various types of soils. However, there are exceptions in that soils of the same sort may develop from several different geologic formations. For example, the soil expert does not differentiate between the residual soils of the Tomstown, Allentown and Beekmantown formations nor between the soils of the various kinds of gneisses. On the other hand, a single geologic formation may give rise to more than one kind of soil. Nevertheless, a person familiar with the rock formations can generally predict the character of the surface soil, especially if he takes into consideration the topographic features and the agents of transportation at work in the region.

In a report[39] of the Bureau of Soils of the U. S. Department of Agriculture, the soils of Northampton County are briefly described. Portions of this report are quoted inasmuch as the Government report is not readily available to many persons.*

Upland Residual Soils

DEKALB SOILS

"The Dekalb series includes residual soils derived from the weathering of sandstones and shales. The surface soils are generally gray to grayish brown in color, depending largely on the amount of organic matter present. The subsoils are light yellow to yellowish brown. Some included areas are poorly drained, and here the subsoil has a mottled gray, yellow, and drab color. The subsoil usually grades into broken rock and into bedrock at two to five feet below the surface. The largest area of Dekalb soils in Northampton County, composed almost wholly of rough stony land, lies on Blue Mountain. Small areas of stony loam and loam occur on the lower slopes, between the rough land and the Berks soils. On South Mountain, south of the Lehigh River, some areas of Dekalb soils also occur. These are partly rough stony land and partly stony loam. A few areas of loam and silt loam occur here.

"Only a small part of these soils is farmed. Considerable areas are in pasture, but by far the greater part of their area is in forest.

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[39] Shaw, Charles F., McKee, J. M., and Ross, W. G., Reconnoissance Soil Survey of Southeastern Pennsylvania: Field Operations of the Bureau of Soils, 1912, pp. 247-340, Washington, 1915.

* NOTE: The values for farm lands mentioned in the quotations must be recognized as those prevailing in 1912.

Rather low yields of the general farm crops are obtained where the soils are farmed.

BERKS SOILS

"The Berks soils are derived from the weathering of thin-bedded shales and shaly sandstones (Martinsburg formation). They have yellowish-brown to brown surface soils, with yellow or yellowish-brown subsoils of heavier texture. Both the soil and subsoil contain varying quantities of shale fragments, and the subsoil usually grades into a mass of broken shale within the three-foot section.

"The Berks soils extend across Northampton County in a band six to ten miles wide just south of Blue Mountain from the Lehigh River east to the edge of the glaciated region, west of Bangor. The soils occupy country of steeply rolling to hilly topography and are subject to serious damage by erosion. They are low in organic matter, the need for that material being their most evident deficiency.

"The shale loam is almost the only type, though small areas of silt loam and loam were found. The soils are farmed to the general crops of the region, corn yielding 30 to 60 bushels, oats 25 to 50, wheat 15 to 25, potatoes 100 to 200 bushels, and hay from three-fourths to 1¼ tons per acre. Corn, oats, and potatoes, wheat and grass, is the general rotation. The manure produced on the farm is used, but green manuring is not generally practiced, though it would be beneficial. Lime is used extensively and is of great benefit, especially where the land is to be seeded in clover. All crops suffer severely during dry seasons.

HAGERSTOWN SOILS

"The Hagerstown soils have a yellow or reddish-yellow surface soil and a yellow, yellowish-red, or red subsoil. The soil material is derived from massive limestones (Tomstown, Allentown and Beckmantown formations). The Hagerstown areas occupy gently rolling to moderately rolling lowland belts which lie at elevations of 100 to 200 feet or more below the country occupied by the adjoining shale and sandstone soils. Where the rock has been much folded, the exposure of layers of varying hardness and purity, with different rates of weathering, gives a topography marked by low ridges, with irregular outlines and abrupt changes of slope. The typical topography is that of a rolling depression.

"The soils do not suffer much from erosion, and it is only on the steeper slopes that washing causes any appreciable damage.

"As a whole, the Hagerstown soils are well drained. There are a few areas where artificial drainage would be beneficial, but over most

of these soils the rains soak readily through the soils, the excess water escaping downward through underground channels dissolved in the rocks. It is rare that water will stand on the surface of the limestone soils for more than a few hours after the heaviest rain, and ponds or pools are seldom found. Sink holes are a typical feature of the Hagerstown landscape.

"With this exceptionally active drainage, the soils are not droughty. The larger percentage of silt and clay, especially the latter, in the subsoil gives a soil of high capillary power and water-holding capacity. With care to reduce evaporation losses by cultivation, crops can be carried through any but the most severe droughts without serious reduction of yield.

"In Northampton County a belt of Hagerstown soils 6 to 8 miles wide crosses that part of the county lying north of the Lehigh River. Another area lies beyond the mountains south of Bethlehem, to the north and west of Hellertown, and a third along the Delaware in the southeast corner of the county, in Williams Township.

"The soils occupy generally a country of gently rolling topography and have good natural drainage. Practically all of the land is cultivated, the general farm crops, corn, oats, wheat, rye, and grass, being grown. More wheat is grown than usual on the farms of this State. Wheat is put in the rotation after corn and oats, and also after clover, about twice as much wheat being grown as of corn and oats. Grass is seeded with the wheat and usually left for two years. Considerable stock is kept, dairying being the dominant type of farming.

"The loam is the principal type found, but small areas of clay loam also occur. A phase of the loam occurs in a strip 2 or 3 miles wide, extending from Martin Creek to Easton. Here the soil contains an appreciable amount of sand to a depth of six to eight inches, making it lighter and easier to work than the typical soil. This phase is used chiefly for general farming, but there is a relatively large area devoted to trucking and market gardenening. This phase, because of its location and adaptation to trucking, is valued higher than the typical loam. It is held at $100 to $150 an acre. The loam, farther from towns, sells for $75 to $125 an acre, averaging about $100. Crop yields are high. Corn yields about 75 bushels, oats 40 to 50, wheat 25 to 30, rye 18 bushels, potatoes 100 bushels, and hay 1 to 2 tons per acre.

"Lime is of great benefit to these soils and is in general use. Stable manure or green manures give good results, and the former is carefully saved and applied to the land. Commercial fertilizers are in common use.

CHESTER SOILS

"The Chester soils make up one of the most important and extensive series in the Piedmont region of Pennsylvania. The surface soils are typically of brown or yellowish-brown color, and the subsoils yellow, though the subsoil of the heavier types is quite reddish and often grades into a red clay loam or clay within the three-foot section. This variety of material, however, represents a phase condition.

"The Chester soils are found in every county in the Piedmont section of the State, but are most extensively and typically developed in Chester and Delaware Counties. The soils are derived from igneous and metamorphic rocks, principally from gneiss and mica schists, with considerable areas from gabbro and other granitic rocks. The soils occupy rolling to hilly country, with some areas in the more northern counties that approach the mountainous in character.

"In Northampton County the Chester soils occur in one area in Williams Township, occupying a rough, hilly section of the eastern extension of South Mountain. The stony loam and rough stony land make up the larger part of the area, though there are some small occurrences of the loam. As a rule the soils are well drained, and in many places the run-off is so rapid that gullies are formed. Not over one-half of the area can be tilled, the remainder being too steep or too stony for cultivation. The soils are devoted to general farming and pasture, with some fruit growing. The fruit industry could well be extended, as the soils are well adapted to the production of apples. Land values vary widely, ranging from $20 to $75 an acre. Lands suitable for farming are held at an average price of about $50 an acre.

Upland Glacial Soils

DUTCHESS SOILS

"The Dutchess soils are derived from the glaciation of the shales and shaly sandstones that normally give the Berks soils, and are made up partly of glacial till and partly of the weathered shale material, the former usually forming the larger part of the surface soil, and the latter, especially in the loam and shale loam types, most of the subsoil.

"The soils typically have a yellowish-brown or grayish-brown surface soil, from six to ten inches deep, with a yellow, grayish-yellow, or yellowish-brown silty clay or clay loam subsoil, usually containing considerable shale fragments and grading into loose broken shale at from two to four feet.

"Besides the rough stony land, three types were encountered—the stony loam, loam, and shale loam.

"The Dutchess soils occupy the eastern end of Northampton County, extending from the Blue Mountain south to Belvidere and from the

Delaware River west to a line through Mount Pleasant, Ackermanville, and North Bangor. They cover all of Upper Mount Bethel and part of Washington and Lower Mount Bethel Townships.

"The whole area of Dutchess soils is covered with waterworn and glacially scratched stones and boulders. Near the mountain the stones are so numerous as to make cultivation impracticable, the soil being a mass of stones of various sizes, with very little fine earth. Farther south the stone content decreases until near the southern boundary it is a negligible factor in cultivation.

"The areas have a rolling to somewhat hilly topography. They are subject to considerable erosion, and washes and gullies are common on the hillsides. Normally they are well drained, though some, where the glacial till is quite deep, are inclined to be wet. These are usually the more stony areas.

"The stony loam is largely in forest and pasture; and other types are generally farmed. The general farm crops are grown. Corn yields 35 to 60 bushels, oats 25 to 50 bushels, wheat 15 to 25 bushels, potatoes 100 to 200 bushels, and hay 1 to 1½ tons per acre. The soils need lime and organic matter. Land prices vary, depending on type and location. The rough stony soils are worth less than $5 an acre, while the loam and shale loam range from $50 to $75 an acre.

TERRACE SOILS

"Four series—the Chenango, Wheeling, Holston and Birdsboro—include the terrace soils found in this survey. They occupy the benches or terraces along the larger streams and are usually above all but the highest overflows. They represent the alluvial deposits of the streams when they flowed at a much higher level than at present.

CHENANGO SOILS

"The Chenango types have yellowish-brown to reddish-brown surface soils and yellowish-brown to brown subsoils. The subsoils of the heavier types, where not well drained, are dark grayish, or occasionally mottled.* The soils occupy benches and terraces in the glacial region and are most typically developed along the Susquehanna and Delaware rivers.

"The soils generally have a level surface, though some of the higher terraces have been cut by erosion and now have a rolling topography. The soils are normally well drained, there being, usually, a permeable bed of gravel or rounded stones and small boulders in the deeper subsoil. The heavier types, which usually lie next the uplands, are sometimes kept wet by seepage water from the higher lying soils and in some cases are marshy or swampy. The soils, except in rare instances, are not subject to erosion.

* These poorly drained terrace soils with heavy subsoils made up of sandstone and shale material are Holston soils occurring as small areas among the Chenango soils.

"The Chenango soils in Northampton County are found along the Delaware River and Jacoby Creek. Near Portland the soils are stony and underlain by a deep deposit of gravel, and are excessively drained and droughty. The largest area lies east of Martin Creek, and has a level to gently sloping surface and good drainage. The sandy loam and fine sandy loam types are the most extensive, but some gravelly or stony areas are found. The soils here are devoted to general farm crops, of which excellent yields are obtained. Potatoes do well, yielding from 100 to 200 bushels per acre. Alfalfa does well where the land is properly prepared. The soils are deficient in organic matter, and in most cases need lime. Market-garden and truck crops do well, and their production could very profitably be extended. The land is valued at $75 to $150 an acre.

HOLSTON SOILS

"The Holston soils are not extensively developed in this survey, being found only in small areas. The soils occur as second bottoms and terraces along the larger streams, and lie above all but the highest overflows. They represent the deposits made when the streams flowed at higher levels than they do at the present time. The surface soils are grayish yellow to dark grayish brown in color with yellow, gray, or mottled subsoils. Drainage conditions vary greatly. The lighter types are normally well drained, but the heavier often need artificial drainage. Several types were encountered, the silt loam being of greatest extent.

"The Holston silt loam consists of six to eight inches of gray to grayish-brown silt loam, resting on a yellow to mottled silty clay loam, grading with depth into a mottled silty clay. The other types encountered included fine sandy loam, loam, clay loam, and clay, and occurred in very small areas.

"In Lehigh and Northampton counties there are small areas of Holston soils along the Lehigh River and its tributaries. Some truck and garden crops are grown, but the soils are generally utilized for the general farm crops—corn, wheat, and hay. The yields are moderate to large. The soils along the Lehigh River are better drained than elsewhere."

MINERALOGY

By Benjamin L. Miller

The rocks of Northampton County have yielded a rather large number of mineral species; somewhat less than in some of the southeastern counties of the State, but far more than are found in the northern, central and western counties. The variety is due largely to the different types of rock present in the county. These include acid, intermediate and basic igneous rocks, both deep-seated (plutonic) and shallow (extrusive); sedimentary rocks of the principal types—conglomerate, sandstone, shale and limestone—and metamorphic rocks—gneiss, schist, quartzite, marble and slate. The glacial deposits that are thinly spread over most of the county but form a fairly thick cover in the northeast corner, yield a great variety of rocks collected by the ice from a wide area to the northeast. These rocks are composed of many minerals.

In general each type of rock serves as the home of particular minerals, as must be the case since rocks are principally classified by their mineral composition. The metamorphosed igneous rocks contain the largest variety and the slightly altered sedimentary ones the fewest.

Although Northampton County has never had many amateur or professional mineralogists, such as have long been numerous in the Philadelphia region, at different times men living in this county have enthusiastically collected and studied minerals. The region has been visited by many geologists and mineralogists from other parts, many of whom have described the minerals they found here. The museums of Lehigh University, Lafayette College, and the Academy of Natural Sciences of Philadelphia contain fairly complete collections of the minerals of the county. The men who have contributed most to our knowledge of the minerals of the county are Frederick Prime, Jr., Frederick A. Genth, John Eyerman, Edgar T. Wherry, and Frederick B. Peck. The geological bibliography of Northampton County, forming a separate chapter in this volume, lists several papers by these investigators.

The published descriptions of the local minerals are distributed through many volumes, many of which are not readily accessible. They have been brought together in a convenient form by Samuel G. Gordon in his Mineralogy of Pennsylvania.[40] This volume has been freely used in the preparation of this chapter.

In the following descriptions of individual minerals, it will be noted

[40] Special Publication No. 1, Acad. of Nat. Sci. of Philadelphia, 260 pp., Philadelphia, 1922.

that by far the greatest number have been credited to Chestnut Hill, just north of Easton. That ridge of igneous and metamorphic rocks of several different kinds contains the largest assemblage of minerals of any place in the county. The diversity of mineral species is due to the unusual conditions that prevailed there, where igneous rocks and highly magnesian limestones have been intruded by pegmatites, as described elsewhere in this report.

The composition and classification of the minerals of the county is that adopted by Gordon, which in turn is largely taken from Dana's "System of Mineralogy."

Minerals of Northampton County

	Sedimentary rocks	Igneous rocks	Metamorphic rocks
Native elements:			
Graphite			x
Copper	x		
Sulphides:			
Molybdenite			x
Galena			x
Chalcocite			x
Sphalerite			x
Chalcopyrite			x
Pyrite	x	x	x
Marcasite	x	x	x
Halides:			
Halite	x		
Fluorite	x		x
Oxides:			
Quartz	x	x	x
Jasper (ferriferous)	x		
Chalcedony	x		x
Flint (basanite)	x		
Opal	x		x
Cuprite			x
Corundum	x		
Hematite	x	x	x
Martite	x	x	
Ilmenite			x
Spinel			x
Magnetite		x	x
Rutile	x		
Pyrolusite	x	x	x
Brucite			x
Goethite	x		
Turgite	x		
Lepidocroeite	x		
Limonite	x		
Psilomelane	x	x	x

	Sedimentary rocks	Igneous rocks	Metamorphic rocks
Carbonates:			
Calcite	x		x
Aragonite	x		x
Dolomite	x		x
Strontianite			x
Magnesite			x
var. Breunnerite			x
Phosgenite			x
Siderite	x		
Malachite	x		x
Azurite	x		x
Hydromagnesite			x
Zaratite			x
Silicates:			
Feldspar group	x	x	x
Orthoclase			
Microcline			
Microperthite			
Albite			
Oligoclase			
Labradorite			
Anorthite			
Pyroxene group		x	x
Enstatite			
Hypersthene			
Diopside (Sahlite or salite)			
Coccolite			
Augite			
Amphibole group		x	x
Tremolite			
Actinolite			
Nephrite			
Asbestos			
Uralite			
Anthophyllite, var. kupfferite			x
Hornblende			

Minerals of Northampton County—Continued

	Sedimentary rocks	Igneous rocks	Metamorphic rocks
Garnet group:			
Almandite			x
Andradite			x
Other orthosilicates:			
Wernerite			x
Vesuvianite			x
Zircon	x		x
Topaz	x		x
Sillimanite			x
Cyanite	x		
Epidote			x
Allanite			x
Axinite			x
Orthosilicates or metasilicates:			
Calamine	x		
Tourmaline		x	x
Mica group:			
Muscovite	x	x	x
Damourite			
Sericite			
Biotite		x	x
Phlogopite			x
Chlorite group:			
Prochlorite			x
Chlorite-Vermiculite group			x
Eastonite			

	Igneous rocks	Metamorphic rocks	Sedimentary rocks
Other hydrous silicates:			
Serpentine			x
Retinalite			
Marmolite			
Bowenite			
Porcellophite			
Antigorite			
Chrysotile			
Thermophyllite			
Talc			x
Kaolin	x		x
Halloysite	x		
Uranophane			x
Chrysocolla			x
Titanosilicate group:			
Titanite		x	x
Phosphates:			
Apatite			x
Wavellite	x		
Beraunite	x		
Cacoxenite	x		
Autunite			x
Uranates:			
Thorianite			x
Thorium gummite			x
Carnotite			x
Sulphates:			
Barite			x
Celestite			x
Gypsum			x
Molybdate:			
Wulfenite			x

The above list is believed to be fairly complete according to existing information. Unquestionably it will receive additions from time to time, especially in those minerals that occur in microscopic particles in our igneous, metamorphic and sedimentary rocks.

In the descriptions of the individual minerals which follow, only the features that seem to characterize the Northampton County specimens thus far studied are mentioned. The ordinary properties, which are described in all textbooks on Mineralogy, have been largely, if not entirely, omitted. The crystallographic descriptions are also largely omitted. All the available chemical analyses are given, although it should be recognized that some of them may possibly later prove to be inaccurate. Some of the mineral names and compositions used are disputed but space does not permit discussion of the various views.

ELEMENTS

GRAPHITE (C)

Graphite is not an uncommon mineral in Northampton County and yet it has not been found here in commercial quantities. Instead it is merely a minor constituent of several different kinds of metamorphic rocks. In some instances it is in such small particles that it can be determined only by means of the microscope. The following examples are illustrative of its occurrence.

Along the Lehigh-Northampton county line half a mile west of Seidersville graphite occurs in small flakes in a basic gneiss. It is also present in what Wherry[41] has termed a graphite-bearing quartzite which is, in most places, feldspathic. This phase is well represented in Lower Saucon Township from one to two miles southwest of Lower Saucon. The most abundant occurrence of graphite is in a small area of graphite-mica schist closely associated with the coarsely crystalline limestone, one-eighth mile west of Monocacy Creek in the area of pre-Cambrian rocks that extends westward from Pine Top. Some schist here is rich enough in graphite to be of commercial importance if the quantity were sufficient. It has also been reported from pegmatites cutting the gneisses.

Flakes of graphite are common in the very coarsely crystalline Franklin limestone which has been quarried to a small extent along Monocacy Creek and in the tremolite, talc and serpentine of Chestnut Hill above Easton where these limestones have suffered further metamorphism by pegmatitic intrusions. In the Monocacy Creek locality, the graphite occurs frequently as streaks or blackened slickensided surfaces due to movement subsequent to its formation. In the serpentine quarries along the Delaware River, some of the graphite is present in foliated masses.

In the cement rock of the Jacksonburg formation, the carbonaceous matter of these argillaceous limestones has been converted into what is assumed to be graphite along slickensided surfaces. These smooth, brightly polished surfaces are mainly along bedding planes and are abundant in the rock of many quarries. The graphite rubs off readily. Veins of calcite and quartz have developed along these slippage planes and it is common to find fine specimens of veins coated on both walls with a film of graphite.

As a microscopic constituent, graphite is present in most of the commercial slates of the county. Behre[42] describes it occurring in slate as rounded, discoidal or lenticular masses up to 0.015 mm. in diameter.

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[41] Wherry, E. T., Bull. Geol. Soc. America, vol. 29, pp. 385-388.

[42] Behre, Jr., C. H., Slate in Northampton County: Pennsylvania Topog. and Geol. Survey, Bull. M9, p. 90, 1927; Slate in Pennsylvania: Bull. M16, p. 180, 1933.

COPPER (Cu)

Professor E. H. Williams, Jr. has reported the finding of nuggets of native copper in some of the glacial deposits east of Hellertown. He thought that they came from the copper district of Michigan by way of the Mohawk and Hudson River Valleys. The author is more inclined to think that they came from some of the trap rocks of Northern New Jersey.

SULPHIDES

MOLYBDENITE (MoS_2)

Specimens of molybdenite in thin plates along joint planes have been found in the pre-Cambrian rocks of Chestnut Hill and in some loose masses of Byram gneiss about 1½ miles east of Hellertown.

GALENA (PbS)

Occasional small pieces of galena associated with sphalerite have been found in calcite and dolomite veins traversing the serpentine in Chestnut Hill. It has also been noted in the basal Shawangunk conglomeratic sandstones of Lehigh Gap.

CHALCOCITE (Cu_2S)

Chalcocite has been reported from Chestnut Hill. It is also said to occur in the Triassic rocks that contain malachite and may well be present there although the writer has not observed it. The malachite has doubtless resulted from the oxidation of the chalcocite.

SPHALERITE (ZnS)

Sphalerite has been found by the writer in small particles associated with galena in calcite and dolomite veins in the serpentine rocks of Chestnut Hill. It is fairly clear and of a light resinous color.

CHALCOPYRITE ($CuFeS_2$)

Chalcopyrite has been reported from the serpentines of Chestnut Hill.

PYRITE (FeS_2)

Pyrite is a common mineral in Northampton County. In places it is a rather abundant constituent of the gneisses. Recently specimens of Byram gneiss have been brought to the writer from east of Shimersville in which it is well distributed through the normal gneiss and in the pegmatites cutting the gneiss. It occurs almost everywhere in the Hardyston quartzite and by oxidation makes the limonitic stains that render the stone particularly pleasing in color for both residences and public buildings. In the compact quartzite the oxidation has extended inward from the bedding and joint planes less than an inch, but in the more porous beds the pyrite has changed to limonite throughout, even though the layers be six inches or more in thickness.

Pyrite is common in all the limestones, especially in those high in argillaceous and carbonaceous matter. Usually it is in small cubes along bedding planes, but north of Hellertown the writer has found a spherical concretionary mass of pure pyrite about one and one-quarter inches in diameter in the massive dolomitic limestone.

In several of the limonite mines once worked in the county, considerable pyrite was encountered in the lower levels, both in those deposits contained within the Hardyston quartzite and those of the limestones. As suggested in the discussion of the origin of iron ores, this furnishes some evidence for the view that all the iron of the limonite ores was derived from pyrite.

Pyrite is fairly common in the Jacksonburg cement rock, particularly associated with the graphite occurring along slickensided surfaces.

In the Martinsburg slates one occasionally notes small cubes of pyrite or cavities resulting from their removal. Similar occurrences are common in the talc and serpentine of Chestnut Hill.

MARCASITE (FeS_2)

Occasionally marcasite is found in association with pyrite and not sharply distinguished from it.

HALIDES

HALITE ($NaCl$)

Halite is not known to occur in Northampton County, but recently the writer has described[43] casts of halite crystals in an Allentown-Beekmantown limestone quarry belonging to the Keller Estate in Portland. They occur on the bedding planes at several horizons and range in size from one-eighth to one-quarter inch. The casts show hopper-shaped crystals and occur in a dolomite rock containing some argillaceous matter.

FLUORITE (CaF_2)

Fluorite has been found in several places throughout the limestones of Pennsylvania. Wherever noted by the writer it occurs as purple or occasionally light green particles in calcite or dolomite veins. In Northampton County, it has been observed in thin calcite veins in the Beekmantown limestone outcrops in the southwestern part of the race course of the Nazareth Fair Grounds in the southwestern part of Nazareth. In Lehigh County it has been found in similar thin veins within the Jacksonburg limestone in several cement quarries and probably will eventually be found in some of the cement quarries of Northampton County. It also has been reported from the serpentine quarries of Chestnut Hill.

[43] Pa. Acad. Sci. Proc., vol. XI, pp. 55-57, 1937.

OXIDES

QUARTZ (SiO_2)

Quartz is the most widely distributed mineral in the world and occurs in many different varieties and under various conditions. It is an essential or an accessory mineral in practically every type of rock within the county.

The light-colored or acid gneisses contain grains of quartz associated with the feldspars and ferro-magnesian minerals; the dark-colored gneisses in places carry a small amount of quartz; all kinds of gneisses are cut by thin quartz veins and by pegmatites in which the quartz grains may be of considerable size; the Hardyston conglomerates, sandstones and quartzites are composed almost entirely of quartz, both the clastic particles and the cementing matter; all the limestones carry quartz grains and are cut by thin veins in which calcite and dolomite are most abundant but in which quartz is common; the Martinsburg shales contain small quartz grains and in many places have many veins of quartz or quartz and calcite; and the Triassic conglomerates consist of quartz pebbles in a matrix of shale; the shale contains many quartz grains.

Quartz crystals up to four inches in length with well developed crystal faces have been found in cavities in the fractured limestones and loose in the residual soils. In some of the fields north of Farmersville quartz crystals have been found in the surface soils in considerable number.

In that part of the Saucon Valley contained in Lehigh County some masses of ferruginous quartzite, probably from the Tomstown formation, have been found in which each grain has some crystal faces and some individual particles are perfect doubly-terminated crystals. They can readily be seen by means of a small hands lens. It is expected that at some time similar material may be found in the Northampton County portion of this valley.

Genth reports that "fine transparent crystals, some one and a half inches in length and half an inch thick, occur at Crystal Spring, on Blue Mountain, in Bushkill Township."

JASPER (SiO_2)

Yellow and red jasper are abundant in the Hardyston formation of the southeastern part of the county. The yellow variety is most common. Some of it is uniform in color, but most of it is mixed with clear quartz and in many cases stained with pyrolusite. The yellow variety grades from a bright golden yellow to a dark brown and the red from an orange to a brick color or to a deep carnelian red. Within the county no place is known where the jasper is in place. Instead

it occurs as loose fragments in the soils or hillside debris. Some of the pieces are a foot or more in diameter although most are much smaller.

The Indians used the jasper for their arrow and spear heads but do not seem to have quarried it at any place in Northampton County. A few miles to the south near Durham Furnace in Bucks County and near Limeport, Vera Cruz and Macungie in Lehigh County there are extensive diggings where they evidently obtained large supplies.

CHALCEDONY (SiO_2)

In several places in the Saucon Valley there are large masses of dense white to gray chalcedony, particularly on the hillside a short distance northeast of Lost (Hellertown) Cave; occasional loose fragments occur east and southeast of Hellertown.

A variety of chalcedony known as prase has been reported to occur in the gneiss near Redington. It is translucent and has a dull leek-green color. The exact locality is unknown.

OPAL (SiO_2)

Some opal has been noted in association with chalcedony.

FLINT (basanite, hornstone, chert) (SiO_2)

The dark-colored cryptocrystalline varieties of silica, although described as possessing somewhat different properties, are not here differentiated. Specimens of each type and gradations from one to another can be picked up in the fields or along the streams throughout the areas underlain by limestones. The source of the flint is in the Cambrian and Ordovician dolomitic limestones where, in places, it is fairly abundant. All these limestones are rather high in their silica content and the silica has, in part, been segregated by underground circulating waters into lenses or nodules of irregular shape. Many specimens show by their characteristics that they are replacements of the limestone. Along Catasauqua Creek about one mile north of Catasauqua, specimens of *Cryptozöon proliferum* now composed of flint have been found. The lenses are commonly more or less parallel to the bedding planes and range in thickness up to several inches. Occasional masses are several feet in diameter.

The flint in the soils is the residual, relatively insoluble material left behind when the enclosing dolomitic limestones were removed by solution.

The Indians used the black flint of the region for their arrowheads, many of which have been collected all through the county.

CUPRITE (Cu_2O)

Small quantities of cuprite have been found at Chestnut Hill.

CORUNDUM (Al_2O_3)

Small angular to subangular grains of corundum were found by B. F. Buie in his microscopic examination of the insoluble residues of the Allentown limestones east of Bethlehem.

HEMATITE (Fe_2O_3)

Hematite as a red ocherous coloring matter is fairly common throughout the rocks of the county. It has been formed from pyrite and is commonly associated with limonite. Earthy forms of hematite occur about the old iron mines.

The soft non-magnetic iron ore obtained from many mines throughout the county was called hematite or brown hematite, which is mineralogically incorrect as it actually was limonite.

MARTITE (Fe_2O_3)

Martite is hematite in octahedra or cubes pseudomorphous after magnetite or possibly pyrite. It has been noted in several localities but particularly in the gneisses south of Redington.

ILMENITE ($FeTiO_3$)

Ilmenite is a common constituent of the metamorphic crystalline gneisses of the region, occurring in small grains associated with magnetite. The black sand resulting from the concentration of the heavy minerals from the decomposed gneisses practically always contains ilmenite. It has also been listed from Chestnut Hill.

SPINEL ($MgAl_2O_4$)

Prof. W. T. Roepper reported spinel associated with allanite from the gneisses south of Redington.

MAGNETITE (Fe_3O_4)

Magnetite is a common accessory mineral in the gneisses of the region, especially the more basic varieties. As the containing rocks decompose the small magnetite particles are freed and are concentrated by the hillside run-off following rains and can be readily seen along gullies and in the stream sands. In several places in the county it has been found in sufficient quantities to cause people to sink prospect holes but without locating the mineral in commercial quantities. In the adjoining counties of Bucks and Lehigh, magnetite mines have been worked with success.

RUTILE (TiO_2)

The only known occurrence of rutile in Northampton County is in the heavy insoluble residues of the dolomitic limestones of the Allentown formation. B. F. Buie found many specimens in his microscopic examination of residues from the dolomitic limestones east of Bethlehem.

PYROLUSITE (MnO_2)

Dendrites of pyrolusite, resembling ferns and frequently so designated, are common in the rocks of the region. Extending in from the cracks in the rocks the dendrites are very conspicuous, especially in the talc and serpentine rocks of Chestnut Hill and in some of the limestones.

Nearly all the limonite ores, once so extensively mined in this region, carried some manganese either as pyrolusite or psilomelane. Some of the "mountain ores" were especially high in manganese.

The finest specimen of pyrolusite known to the writer was found in the Wharton Mine, about one and a half miles southeast of Hellertown at a depth of 150 feet. It is a dendritic mass several inches high. The specimen is in the museum of Franklin and Marshall College at Lancaster, Pa.

The interior of some of the limonite geodes obtained from some of the old mines is coated with a dense black glossy layer. Edgar F. Smith[44] analyzed such a coating from a specimen obtained near Mountainville, Lehigh County, with the following results: MnO_2 82.66, Mn_3O_4 3.13, Fe_2O_3 4.21, Al_2O_3 tr., SiO_2 9.93.

Similar material occurs in the mines of Northampton County. Genth[45] reports that "it occurs in small rhombic crystals in geodes, frequently associated with turgite in limonite beds, especially in Williams and Saucon townships, Northampton County."

BRUCITE ($Mg(OH)_2$)

Brucite occurs in the serpentine deposit in Chestnut Hill.

GOETHITE ($Fe_2O_3.H_2O$)

Goethite has usually not been distinguished from other hydrated iron oxides but it appears to be present in most of the brown iron ore deposits of the region, particularly in the iron geodes that were abundant in some of the limonite iron mines. It has been described in the literature from iron mines at Bingen and South Easton.

TURGITE ($Fe_2O_3.H_2O$)

Turgite has been confused with others of the iron oxides. Posnjak and Merwin[46] make the statement that "the fibrous mineral *turgite* is variable in composition and considerable evidence is given that it probably represents solid solutions of goethite with hematite together with enclosed and absorbed water."

Reddish iron oxides are not uncommon in the numerous limonite iron ore deposits in Northampton County. Many of these specimens

[44] American Chemical Journal, vol. 5, p. 277, 1883.
[45] Report B, Pennsylvania Second Geol. Survey, p. 46.
[46] American Journal of Science, 4th ser., vol. 47, p. 347.

have been called turgite. Eyerman[47] gives the following description and analysis.

Turgite, as a beautiful red incrustation, is found on the interior surface of limonite geodes at the Glendon, Easton, mines.

Fe_2O_3	86.41
MnO	8.60
H_2O	5.06

LEPIDOCROCITE ($Fe_2O_3 \cdot H_2O$)

Lepidocrocite is regarded as a variety of goethite. Posnjak and Merwin[48] give analyses of two specimens from (South?) Easton. The first one is described as "micaceous, orange red, on fibrous goethite" and the second "consisted of scales set edgewise and closely aggregated, on fibrous goethite."

	1	2
Fe_2O_3	85.80	82.67
FeO	1.47	1.82
Al_2O_3	——	0.24
MnO_2	trace	1.24
MgO	——	0.12
SiO_2	0.91	0.92
CO_2	0.90	1.09
H_2O	11.02	11.68
	100.10	99.78
$\frac{H_2O}{Fe_2O_3}$	1.14	1.25

It is believed that careful search will show the presence of lepidocrocite in many, if not most, of the Northampton County limonitic ore deposits.

LIMONITE ($Fe_2O_3.H_2O$)

Hydrated iron oxides are abundant throughout the county. The term limonite is used to designate those mixtures of ferric iron minerals from which the constituents have not been identified. The principal constituents are goethite, lepidocrocite, turgite, hematite, and jarosite.[49] The brown limonite was the principal constituent in the numerous brown iron ore mines once worked but now abandoned. The miners called it brown hematite. Undoubtedly much of what has been loosely called limonite is actually goethite or lepidocrocite. It occurs in many forms. The earthy variety mixed with clay is known as ocher and has been used for paint. The shelly, stalactitic and geode varieties are common. The black varnish-like botryoidal lining of geodes and other cavities reveals a fibrous structure upon fracturing. Although this has been called limonite in the past, it probably is goethite.

[47] The Mineralogy of Pennsylvania, Part II, p. 22, 1911.
[48] American Journal of Science, 4th ser., vol. 47, pp. 316, 345-346.
[49] Galbraith, F. W., Am. Mineral., vol. 22, p. 1008, 1937.

Limonite is the chief coloring matter of most of the rocks of the region. The iron was originally derived from pyrite, siderite and the various ferro-magnesian minerals of the crystalline rocks. Pseudomorphs of limonite after pyrite have been found at Chestnut Hill and elsewhere.

PSILOMELANE (MnO_2 + impurities)

Most of the limonite iron ores of the region contain some manganese and in a few places considerable percentages of it. The ochér in some localities has enough manganese to be called umber. The only place where umber has been mined in Northampton County is on the south side of Quaker Hill, a few miles north of Bethlehem. Although some of the manganese in the iron ores and umber may be in the form of pyrolusite it seems that more exists as psilomelane and of the variety known as wad.

Edgar T. Wherry[50] gives an analysis, made by J. S. Long, of psilomelane associated with beraunite from an old limonite iron mine one mile southeast of Hellertown. It is as follows: Fe_2O_3 4.5, Mn_2O_3 50.5, P_2O_5 3.2, H_2O 22.1, SiO_2 12.0.

Alkalies and alkaline earths present but not determined.

Eyerman[51] says that he has "observed some beautiful specimens of dendritic wad, coating the limonite, at the Ackerman mine, south from Glendon."

CARBONATES

CALCITE ($CaCO_3$)

Calcite is an abundant mineral throughout the limestone areas of Northampton County. Good crystals are not common although small ones have been noted in many places in vugs and other cavities in the limestones and in the serpentine rocks of Chestnut Hill. Calcite veins are abundant in the cement limestones and other calcareous rocks and not uncommon in some places in the slates. Stalactites of calcite occur in the caves and smaller openings of the limestones.

Some limestone beds within the county are almost pure calcium carbonate, but nearly all contain much magnesium carbonate, silica, aluminum oxide, and iron oxides.

Calcite from Williams' quarry containing strontium has been called strontianocalcite.

ARAGONITE ($CaCO_3$)

Beautiful acicular and tree-like crystals of aragonite have been observed in Lost Cave at Hellertown, in the cave at Redington and in open crevices in limestone quarries. Many of the cave stalactites are composed of aragonite. Eyerman, in his Mineralogy of Pennsylvania,

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[50] Proceedings of U. S. National Museum, vol. 47, p. 508.
[51] Mineralogy of Pennsylvania, Part 1, 1889.

Part I, reports it as occurring "in silky snow white masses and fibres associated with serpentine" in the serpentine quarry along the Delaware River, Easton.

DOLOMITE ($CaMg(CO_3)_2$)

Dolomitic limestones are widespread throughout the limestone belts of the county. In small cavities in these limestones, it is not unusual to find small saddle-shaped crystals of dolomite.

In the serpentine quarries in Chestnut Hill, Easton, there is considerable dolomite of a beautiful pink color. Specimens can be obtained in which the colored dolomite distributed through the light green serpentine produces a most pleasing effect. Rock of this character was once quarried along Bushkill Creek and marketed in the form of polished tile used for interior decoration.

The magnesium carbonate in the magnesian limestones ranges up to approximately 45 percent. With the exception of the Jacksonburg limestones used in the manufacture of portland cement and occasional beds within the Beekmantown formation, it is unusual to find analyses of any limestones from Northampton County with less than 5 percent $MgCO_3$, thus indicating the widespread occurrence of dolomite.

STRONTIANITE ($SrCO_3$)

Gehman reports strontianite from a serpentine quarry along Bushkill Creek.

MAGNESITE, VARIETY BREUNNERITE ($MgCO_3$)

One might expect magnesite to occur in the serpentine rocks of Chestnut Hill, Easton, but so far as known the ordinary white variety has not been observed there. The ferriferous variety known as breunnerite, however, has been reported by Genth in his Mineralogy of Pennsylvania, p. 158.

PHOSGENITE ($Pb_2Cl_2CO_3$)

This chlorocarbonate of lead has been reported from Williams' quarry, Easton.

SIDERITE ($FeCO_3$)

In many of the brown iron ore mines of the region siderite is common, especially in the lower levels. It is light yellowish-gray to light brown and is usually in the dense amorphous form. Small crystals occur in some places.

Genth, in his Mineralogy of Pennsylvania, pp. 160-161, gives an analysis made by Prof. W. T. Roepper of a specimen from Wurst's mine, Hellertown. It is as follows: $FeCO_3$ 90.51, $MnCO_3$ 0.78, $MgCO_3$ 1.20, SiO_2 8.00.

MALACHITE ($Cu_2(OH)_2CO_3$)

Small amounts of malachite have been found in the Triassic limestone conglomerates about three-fourths mile southwest of Leithsville. The malachite forms thin coatings over limestone pebbles or coating the cavities formed by the solution of such pebbles. Some prospect mining was done here, but the venture was a failure. It has also been observed in the serpentine quarries of Chestnut Hill.

AZURITE ($Cu_3(OH)_2(CO_3)_2$)

Azurite is almost everywhere found in association with malachite.

HYDROMAGNESITE ($Mg_4(OH)_2(CO_3)_3.3H_2O$)

Eyerman reports, in American Geologist, volume 34, page 45, the presence of hydromagnesite in the serpentine of Chestnut Hill.

ZARATITE ($Ni_3(OH)_4CO_3.4H_2O$)

Eyerman, in his Mineralogy of Pennsylvania, Part II, describes an occurrence of zaratite as follows:

> I have found a single, but quite large, specimen of emerald-nickel, as an apple-green incrustation in altered serpentine, at Williams' Delaware quarry, Easton.

SILICATES

FELDSPARS

The feldspars form a large and essential part of the gneisses and pegmatites of the county. In the pegmatites the crystals range up to an inch or more in size. They are also present in the Hardyston sandstones and in microscopic size in the limestones and other sedimentary rocks. Microscopic studies have shown the presence of orthoclase ($KAlSi_3O_8$), microcline ($KAlSi_3O_8$), microperthite (albite-orthoclase), albite ($NaAlSi_3O_8$), oligoclase $\begin{pmatrix}6NaAlSi_3O_8\\1CaAl_2Si_2O_8\end{pmatrix}$ to $\begin{pmatrix}3NaAlSi_3O_8\\1CaAl_2Si_2O_8\end{pmatrix}$ labradorite $\begin{pmatrix}1NaAlSi_3O_8\\1CaAl_2Si_2O_8\end{pmatrix}$ to $\begin{pmatrix}1NaAlSi_3O_8\\3CaAl_2Si_2O_8\end{pmatrix}$, and anorthite ($CaAl_2Si_2O_8$). More investigations will doubtless reveal the presence of still other members of the feldspar group than those listed in the table.

Orthoclase is most common in the gneisses of the region. An analysis by Eyerman[52] of a light red crystal of orthoclase from Chestnut Ridge is as follows:

SiO_2	66.14	Na_2O	3.00
Al_2O_3	18.96	Ign.	.40
Fe_2O_3	.62		
CaO	.08		99.99
K_2O	10.79	Sp. gr. — 2.597	

[52] American Geologist, vol. 34, p. 45.

ENSTATITE ($MgSiO_3$)

The microscopic examination of some of the gneisses of the region has shown the presence of enstatite.

HYPERSTHENE ($(Fe, Mg)SiO_3$)

Hypersthene occurs as an important mineral constituent of some of the gneisses of the region and has been recognized by microscopic investigations.

DIOPSIDE (Sahlite or Salite) ($CaMg(SiO_3)_2$)

Diopside occurs in pure specimens of light green color with a somewhat pearly luster in the serpentine quarry along the Delaware River north of Easton. Recently the writer found some masses about six inches in diameter showing fine parallel partings. Eyerman, in his Mineralogy of Pennsylvania, Part II, reports some specimens found in 1856 and labeled "sahlite." He analyzed this (No. 1) and some other specimens labeled "augite" consisting of "eight-sided greenish prisms" (No. 2).

	1	2
SiO_2	51.05	53.39
Al_2O_3	0.73	0.73
Fe_2O_3	——	1.67
FeO	——	0.97
CaO	24.59	24.30
MgO	23.80	17.98
H_2O	0.14	1.02
	100.31	100.06
Sp. gr. —	3.411	3.111

COCCOLITE (calcium iron pyroxene)

Cabeen reports coccolite, a variety of hedenbergite from Williams' quarry, Easton.

AUGITE ($CaMg(SiO_3)_2$ with Al and Fe)

Augite is an important constituent of the gneisses of the district. It has been noted in the serpentine at Chestnut Hill.

TREMOLITE ($Ca_2Mg_5(OH)_2Si_8O_{22}$)

Tremolite is abundant in association with the serpentine and talc of Chestnut Hill, north of Easton. Large masses of rock composed mainly of white lath-shaped or fibrous crystals occur in some of the serpentine quarries. An analysis by Eakins, given by Merrill,[53] of tremolite from the old Wolf quarry, Easton, is as follows:

SiO_2	58.27	K_2O	0.42
Al_2O_3	0.33	Na_2O	1.25
Fe_2O_3	trace	Ignition	1.22
MnO	0.08		
CaO	11.90		99.40
MgO	25.93	Sp. gr. — 2.998	

[53] Proceedings of U. S. National Museum, vol. 12, p. 600.

ACTINOLITE ($Ca_2(Mg, Fe)_5(OH)_2Si_8O_{22}$) and varieties

Eyerman, in his Mineralogy of Pennsylvania, Part I, gives the following descriptions of actinolite from Easton.

Last fall (October 1888), I discovered some fine crystals of actinolite associated with tremolite, a few rods northwest of the Electric Railroad car house, College Hill, Easton. Massive and crystallized, it is found at the following localities in the vicinity of Easton: Herster's Dam one and one-half miles west of the city; at several talc openings along the Bushkill Creek; along the Delaware River and at several places along the Chestnut Ridge north from the city.

In a later publication Eyerman[54] refers to "grayish-green striated crystals" of actinolite from the "Reservoir Quarry," Easton, and gives the following analysis: SiO_2 54.55, FeO 2.27, CaO 13.43, MgO 28.05, Ign 1.25.

Nephrite.—Eyerman, in Mineralogy of Pennsylvania, Part II, describes a variety of actinolite occurring as "green bladed. Syenite ridge, Easton" and calls it *nephrite.* He gives the following analysis:

SiO_2	60.26	Ign.	2.29
Al_2O_3	2.57		
FeO	1.85		100.42
CaO	13.40	Sp. gr. — 3.010	
MgO	20.05		

Asbestos.—The talc and serpentine quarries of Chestnut Hill show much asbestos, part of which seems to be the actinolite type, of both the slip fiber and cross fiber forms. The latter occurs as veins up to one-quarter inch wide cutting the serpentine in all directions. The slip fiber variety occurs along fault planes and specimens with fibers two feet long have been obtained. Both varieties, when fresh, are white, massive, brittle mineral scarcely showing any indication of its fibrous character. On weathering, however, the fibers separate readily and become soft and silky. No commercial use has ever been made of the asbestos from this locality.

Eyerman[55] gives an analysis of "long pure white fibres from the Delaware River quarry" as follows: SiO_2 55.25, FeO 2.18, CaO 12.66, MgO 30.19.

Uralite.—Peck[56] describes a rock associated with talc in one of the quarries of Chestnut Hill "consisting of green augite (now mostly altered to uralite), orthoclase and microperthite; also having much dark mica of the biotite variety, and some ore, probably magnetite."

ANTHOPHYLLITE, variety Kupfferite
(high magnesian iron silicate)

An asbestiform form of kupfferite has been found in Williams' quarry, Easton.

[54] American Geologist, vol. 34, p. 47.
[55] American Geologist, vol. 34, p. 47.
[56] Report No. 5, Topographic and Geologic Survey of Pennsylvania, p. 20, 1911.

HORNBLENDE (Ca,Mg,Fe,Al, and Na silicate)

Hornblende constitutes a very important part of nearly all the gneisses and pegmatites of Northampton County. It is rarely absent even in the lighter-colored gneisses and may constitute practically all the rock in the darker more basic varieties. In several of the pegmatites some of the individual hornblende crystals may be over an inch in diameter. Specimens with crystal faces are rare.

ALMANDITE ($Fe_3Al_2(SiO_4)_3$)

Some of the garnets contained in the gneisses of Northampton County may be of the almandite variety. This seems particularly probable inasmuch as almandite garnets have been identified from Lehigh County localities.

ANDRADITE ($Ca_3Fe_2(SiO_4)_3$)

Garnets provisionally grouped in the andradite class have been found in a few places in Northampton County. Several areas of garnetiferous gneisses lie to the southeast, east and northeast of Hellertown.

Eyerman, in his Mineralogy of Pennsylvania, Part II, gives an analysis of a dark brown andradite garnet from the Weber Farm (allanite locality) south of Redington, Lower Saucon Township. It is as follows:

SiO_2	35.46	CaO	29.60
Al_2O_3	7.50		
Fe_2O_3	26.04		99.74
MnO	1.14	Sp. gr. — 3.790	

WERNERITE (Scapolite) (complex Ca,NaAl silicate)

Eyerman, also in Part II, classes as wernerite "an altered scapolite of lavender-pink color from Mineral Spring quarry, Easton" and gives the following analysis:

SiO_2	54.61	K_2O	1.25
Al_2O_3	24.79	H_2O	1.76
Fe_2O_3	0.32	Cl	2.00
CaO	2.06		
MgO	9.01		100.21
Na_2O	4.41	Sp.gr. — 2.610	

George W. Gehman has found specimens of wernerite in the Delaware River serpentine quarry.

VESUVIANITE (a basic calcium-aluminum silicate)

Prof. C. K. Cabeen reports vesuvianite from Williams' quarry, Chestnut Hill.

ZIRCON ($ZrSiO_4$)

Genth[57] reports zircon in Northampton County in the following quoted paragraphs:

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[57] Mineralogy of Pennsylvania: Pennsylvania Second Geol. Survey, Report B, p. 76 1875.

Very fine clove-brown quadratic prisms with pyramids from one-sixth to two inches in length and one-tenth to one-half inch in breadth have formerly been found imbedded in the talc of Chestnut Hill, near Easton.

Associated with allanite in small crystals of the usual form, rarely half an inch in length and partly altered on all the planes, except the zirconoid, the color of the latter being brownish-black, while the others are gray, it is found in Lower Saucon Township, Northampton County, five miles east of Bethlehem; and under similar circumstances, three-fourths of a mile north (?) of Bethlehem.

It is found in minute slender crystals in the South Mountains one mile east of Hellertown.

Eyerman, in his Mineralogy of Pennsylvania, Part II, also describes zircons from Chestnut Hill as follows:

Without doubt, the most interesting, as well as the largest zircons, found in the State, are those which were discovered many years ago, in the biotite at Easton; approximately, two dozen isolated crystals were found. Eight in my possession, are elongated prisms m(110,1) with p(111,1); some double. Color: clove-brown; the termination on the largest crystal is very black-brown, the prism face m clove-brown, the two being sharply separated by the angle line. The lengths are

$m\text{-}p$ = 15 mm	m = 7 mm	$m(p)2$ = 15 mm
m = 5 mm	m = 5 mm	$m(p)2$ = 17 mm

George W. Gehman has found beautifully formed crystals of zircon up to 1½ inches long in the Delaware River serpentine quarry.

Recently B. F. Buie has found grains of zircon in the residues of the dolomitic limestones of the Allentown formation east of Bethlehem. The grains range from colorless to pale yellowish brown or pale rose pink. Some of them contain inclusions of an undetermined mineral.

Wherry[58] in his microscopic studies of gneisses of the Bethlehem region has found zircon in several specimens.

TOPAZ ($(Al(F,OH)_2)AlSiO_4$)

Eyerman, in his Mineralogy of Pennsylvania, Part II, describes small cream yellow crystals of topaz from Chestnut Hill.

B. F. Buie has found colorless grains of topaz in the residues of the dolomitic limestones of the Allentown formation east of Bethlehem.

SILLIMANITE (Al_2SiO_5)

Wherry[59] has reported abundant sillimanite in quartz-mica schists of Northampton County. It "occurs in long slender prisms, mostly curved or bent slightly and in subparallel arrangement." In one locality just across the line in Lehigh County, one mile west of Seidersville, it constitutes 35.1 percent of the rock. He also describes the presence of sillimanite in quartz-mica schists occurring two miles southeast of Freemansburg, slightly more than one mile south of Island Park and about 2½ miles east of Hellertown.

[58] Bull. Geol. Soc. Am., vol. 29, pp. 375-392.
[59] Idem. vol. 29, pp. 375-392.

CYANITE (Al_2SiO_5)

Small microscopic grains of colorless to pale bluish-green cyanite have been noted by B. F. Buie in the insoluble residues of Allentown dolomitic limestones east of Bethlehem.

EPIDOTE (complex Ca,Al,Fe silicate)

Epidote is a very common mineral in the light and dark-colored pre-Cambrian gneisses of Northampton County. It has been formed from feldspars and hornblende. In some places, especially in the vicinity of Hexenkopf Hill, specimens of gneiss can be obtained in which approximately half the rock is epidote. It is also common in the pegmatites. Bands or streaks of almost pure epidote occur. Slickensided surfaces are commonly coated with a thin layer of epidote In almost all cases the mineral is so fine-grained as to appear to the naked eye to be a homogeneous amorphous mass with a dull pistachio-green color, but small brilliant crystals, readily visible, have been observed, mainly along fault planes.

ALLANITE (complex Ca,Fe,Al,Ce silicate)

Allanite has been found in several places in the gneisses of South Mountain. It was first reported from Bethlehem by Genth[60] in 1855 who published an analysis. Later a mass about 100 pounds in weight was found on the mountain south of the Lehigh University buildings. Since that time it has been noted in several localities in the vicinity of Bethlehem and Redington. It occurs in grains readily visible to the naked eye. Generally it is overlooked because of its resemblance to hornblende.

The analysis given by Genth represents the average of two analyses made by Peter Keyser. It is as follows:

SiO_2	33.31	CaO	11.28
Al_2O_3	14.34	MgO	1.23
Fe_2O_3	10.83	Na_2O	0.41
FeO	7.20	K_2O	1.33
Ce_2O_3	13.42	H_2O	3.01
$(Di,La)_2O_3$	2.70		
			99.06
		sp. gr. — 2.610	

AXINITE (complex Ca,Fe,Mn,Al,B silicate)

The only locality in Northampton County where axinite crystals have been found is in the vicinity of Camels Hump, north of Bethlehem. Prof. B. W. Frazier[61] published an article describing the crystal forms observed on these specimens and from this article the following passages are abstracted.

[60] Am. Jour. Sci. and Arts, 2nd ser., vol. 19, p. 21.
[61] Am. Jour. Sci., 3rd ser., vol. 24, pp. 439-447, 1882.

The crystals of axinite . . . were found in the heap of debris surrounding an abandoned pit, which had been sunk in exploring for ore on a farm in Northampton County, Pennsylvania, about three miles north of Bethlehem.

The locality was discovered by Professor F. Prime, Jr., of the Second Geological Survey of Pennsylvania, and was brought by him to the notice of the late Professor W. T. Roepper, who determined the mineral to be axinite, and who secured a number of specimens of it. The determination of the mineral as axinite was made also, independently, by Dr. F. A. Genth, the mineralogist of the Survey . . .

The crystals occur in a rock containing crystalline hornblende, apparently mixed intimately with axinite, and traversed by numerous narrow veins of axinite. In some of these veins the axinite is mixed with asbestos. Probably owing to this association the axinite itself sometimes assumes a fibrous structure. Wherever in the veins a free surface is exposed, it is thickly covered with implanted crystals of axinite; irregularly crowded together. Some of the crystals are colorless, others and the crystalline variety which fills the veins have a pale brown color. The color in some cases is chiefly superficial from the presence of a thin, brown incrustation which occurs sometimes in dendritic forms. The luster of the crystals varies from dull to highly brilliant.

The crystals have the usual sharp, axe-like shape, which originally suggested to Haüy the name of the mineral . . .

The crystals are in general small, varying from a fraction of a millimeter to several centimeters in length.

Several specimens of the material in the mineralogical collections of Lehigh University were originally in Professor Roepper's private collection.

So far as known no other specimens have ever been found in that locality. The rock is a phase of the pre-Cambrian gneiss that constitutes the Camels Hump.

CALAMINE ($H_2Zn_2SiO_5$)

The only known occurrence of calamine in Northampton County is that reported by John Eyerman, in his Mineralogy of Pennsylvania, Part I. His statement follows: "Last summer (1888) I obtained some good crystals (of calamine) of a dark brown color on limonite and coating the interior of geodes, from an abandoned mine shaft on the land of S. von Steuben, one-quarter mile W. of Dryland Station, Northampton Co." The locality probably is close to the Steuben station of the Lehigh & New England R. R.

TOURMALINE (complex Al,Mg,Fe,B, etc. silicate)

Tourmaline has been found in quartz or pegmatite veins cutting the gneisses of Northampton County. Some of the pegmatites of Chestnut Hill contain black crystals over half an inch long.

Eyerman[62] gives the following description:

Generally occurs massive, imbedded in quartz, above the devil's oven, Bushkill Creek, west of Easton. Good crystals up to 60 millimeters showing *a o m* planes are occasionally found, and an analysis of one of these crystals is appended. Some brilliant black striated crystals 40 millimeters long have been found at Marble Hill (continuation of Chestnut Hill across the Delaware River in New Jersey), imbedded in orthoclase.

[62] American Geologist, vol. 34, pp. 45-46, 1904.

Analysis of Easton tourmaline

SiO_2	35.57	FeO	9.40	Li_2O	trace
TiO_2	.18	CaO	3.42	H_2O	4.23
B_2O_3	10.10	MgO	8.29	F	undetermined
Al_2O_3	24.72	Na_2O	2.10		
Fe_2O_3	1.17	K_2O	.40		99.58

Sp. gr. — 2.991

B. F. Buie has found rounded grains of yellow, brown, black and green tourmalines fairly abundant in the insoluble residues of the Allentown limestones.

MUSCOVITE ($H_2KAl_3(SiO_4)_3$)

Muscovite in small crystals is a rather common constituent of the Byram and other gneisses of Northampton County. It occurs in larger crystals in occasional pegmatites, and especially in the pegmatites and serpentine of Chestnut Hill. However, in no place in the region, has it any commercial value.

Eyerman (Part II) gives the analysis of a muscovite occurring in "large crystals on syenite ridge, Easton," as follows:

SiO_2	44.52	FeO	1.14	H_2O	4.72
Al_2O_3	34.02	CaO	0.13	F	trace
Fe_2O_3	2.51	Na_2O	3.01		
		K_2O	9.47		99.52

Sp. gr. — 2.879

Damourite.—The Second Geological Survey of Pennsylvania referred to the mica occurring in the Paleozoic limestones of the State, formed from the muddy sediments mixed with the calcareous oozes, as damourite. The writer prefers to call this material sericite.

Sericite.—The Cambrian and Ordovician limestones of the county are mainly fairly high in silica and aluminous matter which represents mud that was washed into the Paleozoic sea when these limestones were forming. In the various movements that have taken place since their deposition this argillaceous and siliceous material has been metamorphosed to sericite. It forms glistening surfaces along the bedding planes and in many places is a conspicuous characteristic of these rocks. Also the mica in the slates of the county, and which produces the fine cleavage, is mainly sericite.

BIOTITE ($H_2K(Mg,Fe)_3Al(SiO_4)_3$)

Biotite in small flakes is abundant as one of the constituents of some of the basic gneisses of the county and in larger pieces in some pegmatites.

It is a rather common mineral in the serpentine and pegmatites of Chestnut Hill, Easton. Analyses of specimens from this locality have been published as follows:

Analyses of biotite from Chestnut Hill, Easton

	1	2	3	4		5
SiO_2	34.82	41.07	41.12	40.32	(or 40.11)	40.32
TiO_2	2.00					
Al_2O_3	16.91	23.34	17.23	18.03		17.60
Fe_2O_3	4.19	4.35	3.14	5.80		4.30
FeO	15.89					15.01
MgO	13.98	23.00	24.00	24.79		14.40
CaO			0.89	0.46		
Na_2O	2.49	1.60	0.42	trace		
K_2O	7.48	6.30	9.50	10.50		
F		trace	trace			
H_2O	1.79	0.26	3.56	0.25		
	99.62	99.92	99.86	100.15		
Sp. gr.		2.712		2.880	(or 2.881)	

1. Knop: Zeit. für Kryst. und Mineral, vol. 12, p. 603.
2. Eyerman: "Silver-white; the old 'water Lot,' Chestnut Hill." American Geologist, vol. 34, p. 46, and Mineralogy of Pennsylvania, Parts II and V.
3. Eyerman: "Light brown; west Chestnut Hill, Easton." References as above.
4. Eyerman: "Brown, resembling muscovite; Syenite ridge, Easton." References as above.
5. Eyerman: "Darker." Mineralogy of Pennsylvania, Parts II and V.

PHLOGOPITE

In the serpentine quarries of Chestnut Hill one can frequently find excellent specimens of phlogopite, some of which are of fair dimensions, up to half an inch in diameter. Some of the material has been altered to vermiculite.

PROCHLORITE (Chlorite?)

Eyerman[63] has given two analyses of minerals from Chestnut Hill which he calls prochlorite. It is questionable whether the minerals which he has studied should not be called chloritic vermiculites. Chloritic minerals are common in association with the serpentine and talc deposits of that locality.

Eyerman's descriptions and analyses are as follows:

Two altered specimens from west Chestnut Hill, Easton, have been analyzed: blue-green (olive green) (512) and light-green (513)."

	512	513
SiO_2	33.96	34.01
Al_2O_3	14.41	15.74
FeO	3.81	5.70
CaO	0.12	0.14
MgO	34.20	31.20
H_2O	12.60	12.69
	99.10	99.48
Sp. gr. —	2.603	2.533

[63] American Geologist, vol. 34, pp. 46-47, and Mineralogy of Pennsylvania, Part II.

Genth[64] in his description of prochlorite makes the following statement: "With the allanite at Bethlehem (Redington?) a variety of very dark blackish-green color and crypto-crystalline, scaly structure is found, resembling thuringite, which, in the absence of investigation, I will merely mention here."

CHLORITIC VERMICULITES

Eyerman has described an altered biotite of a light green color from Chestnut Hill which he named *eastonite*.[65] Clark and Schneider[66] have described a "chloritic vermiculite" from old Wolf quarry, Chestnut Hill. It is light yellowish-green and occurs in a compact tremolite rock. An analysis was made by Merrill.

In the following analyses, 1 is by Eyerman and 2 by Merrill.

Analyses of chloritic vermiculites

	1		2
SiO_2	42.37		43.71
Al_2O_3	12.27		3.59
Fe_2O_3	0.92		0.90
FeO	0.60		
MgO	30.15		38.58
CaO	0.24		
Na_2O	1.58		0.13
K_2O	1.95		2.22
		(at 105°	0.46
H_2O	9.99	(at 250-300°	0.09
		(at ignition	10.70

SERPENTINE ($H_4Mg_3Si_2O_9$)

The serpentine of Northampton County is confined to Chestnut Hill, Easton, where it has long been quarried. Associated with the serpentine are many minerals, the most abundant being tremolite, talc, asbestos, and dolomite. Eyerman[67] has made analyses and has described the following varieties from that locality—precious or noble, retinalite, marmolite, bowenite, williamsite, porcellophite, chrysotile, and thermophyllite. He gives the following description:

> At Easton, there is an interesting deposit of serpentine, confined, mainly, to a fault between pre-Cambrian gneiss-syenite and dolomitic limestone; this locality is all the more interesting as exhibiting the various stages of alteration, from the limestone-gneiss-amphibole to serpentine; pseudomorphs predominate.
>
> While the percentage of silica is usually constant, the iron, alumina and magnesia vary as the process of alteration has advanced.

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[64] Mineralogy of Pennsylvania, p. 133.

[65] Mineralogy of Pennsylvania, Part II.

[66] American Jour. of Sci., 3rd ser., vol. 42, p. 249.

[67] American Geologist, vol. 34, p. 47, and Mineralogy of Pennsylvania, Part II.

	1	2	3	4	5	6	7	8	9
SiO_2	45.23	44.77	42.44	43.28	44.21	39.83	41.68	42.87	41.55
Al_2O_3 ...			1.13		2.72	6.39	11.33	0.26	
Fe_2O_3 ...		0.51	0.26				3.47		3.90
FeO	3.61	4.77	1.69	2.50	0.52	1.71	0.33	2.35	
CaO			0.23	0.23	0.26	0.07	trace	1.04	
MnO							0.80		
MgO	39.59	45.09	41.45	42.55	40.55	39.92	37.75	40.40	40.15
Na_2O ...						1.11			
H_2O below 105°	0.20		0.20	0.43	0.41	0.20			
H_2O above 105°	11.40	4.96	12.50	11.01	12.02	10.23	4.55	12.98	13.70
	100.03	100.10	99.90	100.00	100.69	99.46	99.91	99.90	99.30
Sp. gr. ..	2.517	2.417	2.793	2.487	2.363	2.718	2.510	2.510	3.39

1. Very light green; Delaware River quarry.
2. Dark oily green; same locality.
3. *Precious;* Williams' Bushkill quarry.
4. Dark oily green; Williams' Delaware quarry.
5. White; resembling the so-called Delaware meerschaum.
6. *Thermophyllite;* Delaware River quarry.
7. Verdolite quarry; altered.
8. Porcellophite, green; Delaware River quarry.
9. Greenish-yellow precious serpentine from Easton.

All of the analyses are by Eyerman with the exception of 9 which was made by Thomson.[68]

Genth[69] describes the serpentines of Chestnut Hill in the following paragraphs:

Precious or *noble* serpentine of rich oil-green color has been found massive and in grains disseminated through calcite at Easton.

The massive common serpentine of a dark green color, often with white narrow veins of carbonate of lime and chrysotile, is found at Easton.

The variety "*bowenite*" of a fine granular texture and of a greenish or reddish-white color and great tenacity is found at Easton. It frequently contains a small quantity of tremolite intermixed.

TALC ($H_2Mg_3Si_4O_{12}$)

Talc from a white to a light green color is abundant in association with serpentine and other metamorphic minerals in Chestnut Hill, Easton. In some places it possesses a distinct foliated structure but in other places it is of the massive variety, steatite. It is usually ground with the serpentine and other minerals for use as a mineral filler but has been quarried separately for talcum powder.

KAOLIN ($H_4Al_2Si_2O_9$)

Kaolin is a general designation of the clay minerals. In the decomposition of feldspar in the gneisses and pegmatites much kaolin has been formed. In the change to kaolin the gneiss crumbles and most

[68] Annals of Lyceum of Natural History, vol. 3, pp. 9-86, 1828.
[69] Mineralogy of Pennsylvania, pp. 114-115.

of the resulting products are removed by erosion. However, in places along the hillsides, the rotten rock, consisting mainly of kaolin and quartz, is not removed and may be ten to twenty feet deep. The kaolin is commonly stained by iron oxide. In no place in Northampton County has it been found practicable to separate the kaolin commercially.

HALLOYSITE ($H_4Al_2Si_2O_9+H_2O$)

A clay described by Eyerman in Mineralogy of Pennsylvania, Part II, is referred to halloysite.

I have found a hydrous manganese-aluminum silicate at the Sampson limonite mine, Cedarville, Easton, where it occurs as a brownish pink clay: an analysis afforded me SiO_2 23.23, Al_2O_3 9.71, Fe_2O_3 4.85, MnO 42.15, CaO 2.91, H_2O 17.15.

URANOPHANE ($CaU_2Si_2O_{11}.6H_2O$)

In the serpentine quarry along the Delaware River road, Easton, specimens of uranophane have recently been found. It occurs as a light yellow encrustation in association with serpentine, talc and other minerals. Credit for recognizing this mineral belongs to George W. Gehman.

CHRYSOCOLLA ($CuSiO_3.2H_2O$)

Small patches of chrysocolla in serpentine have been observed in the serpentine quarries of Chestnut Hill, Easton. It is comparatively rare.

TITANITE ($CaTiSiO_5$)

Wherry[70] has reported titanite as an accessory mineral in a very basic gneiss occurring one mile southeast of (South) Bethlehem. George W. Gehman also reports titanite in the serpentine quarries, Easton.

PHOSPHATE

APATITE ($Ca(F,Cl)Ca_4(PO_4)_3$)

Gehman states that he has found small sky blue crystals of apatite in the west end of Williams' serpentine quarry, Chestnut Hill.

WAVELLITE ($Al_3(OH,F)_3(PO_4)_2.5H_2O$)

The only place in Northampton County where wavellite has been recognized is a small abandoned limonite iron mine about one mile southeast of Hellertown. Wherry[71] has described the occurrence and results of crystallographic measurements. The following quotations are from his paper:

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[70] Bull. Geol. Soc. America, vol. 29, p. 389.
[71] Proc. U. S. National Museum, vol. 54, pp. 379-381.

In an abandoned iron mine one mile southeast of Hellertown, Northampton County, Pennsylvania, the locality of the beraunite described in an earlier paper in this series, wavellite has long been known to occur, and in 1910 the writer found two specimens containing measurable crystals, which are rarely met with in this mineral.

The wavellite is in acicular crystals in divergent groups in cavities in ferruginous sandstone. These are very minute, rarely exceeding 0.1 millimeter in diameter, but their faces are brilliant and yield fairly good reflections, although subparallel intergrowth renders the angles somewhat variable.

All the material which could be spared without destroying the specimens, amounting to 0.4 gram, was submitted to the firm of Booth, Garrett & Blair, of Philadelphia, for analysis, and the results, obtained by Mr. Frederick Wynkoop, of that firm, are:

Analysis of wavellite from Hellertown, Pennsylvania

	1	2	3
Al_2O_3	36.5	0.358	3.03
P_2O_5	33.4	0.236	2.00
F	0.8	0.040	
			13+
H_2O	28.6	1.580	
SiO_2	1.1		
Total (less O = F 0.3)	100.1		

1. Results of analysis; the fluorine figure is known to be too low, but the material available was insufficient for its accurate determination. Two and three, ratios.

This agrees exactly with the Groth formula for the mineral, $(Al(OH,F))_3(PO_4)_2+5H_2O$, which differs from that adopted by Dana in allowing for the fluorine and in recognizing the presence of an additional half molecule of water.

Written in expanded form, this is $3Al_2O_3.2P_2O_5.13(H_2O,2HF)$.

BERAUNITE ($Fe_6(OH)_6(PO_4)_4.5H_2O$)

The rare mineral beraunite is known from only one locality in Northampton County. It has been reported by Wherry[72] and from his article the following paragraphs are quoted:

The rare iron phosphate beraunite was discovered near Hellertown, Northampton County, Pennsylvania, by the department of geology of Lehigh University in 1911. The exact locality is the northeast corner of an abandoned iron-ore pit, one mile southeast of the center of the town. It was analyzed by Mr. J. S. Long, assistant in the department of chemistry, and later more thoroughly studied by Mr. Louis H. Koch, assistant in mineralogy, as part of the work for his degree of master of science at Lehigh. Specimens were brought by the writer to the United States National Museum (Cat. No. 87284), and further investigated and the combined results of all the work are here presented.

The material shows a deep brown nodular crust up to five millimeters thick, and flat radiations up to one centimeter in diameter, on the surface of an iron-stained quartzite. In some specimens it bears implanted globules of psilomelane, yellow needles of cacoxenite, and powdery clay. Internally the crusts are coarsely fibrous, with the fibers perpendicular to the surface, and the material was evidently originally a gelatinous precipitate, which has become hard and crystalline in place, thus representing a "meta-colloid," as defined by the writer in a recent paper.

[72] Proc. U. S. National Museum, vol. 47, pp. 507-509.

Table of Analyses

	1	2	3	4	5	6	7
Fe_2O_3	42.91	52.65	55.61	57.80	57.89	58.69	4.5
Mn_2O_3	15.25	3.88	1.80	1.66			50.5
P_2O_5	28.10	29.27	28.53	27.43	28.33	28.71	3.2
H_2O	10.01	13.59	13.54	12.60	12.43	12.60	22.1
SiO_2	4.02	0.71	0.34	0.55	1.41		12.0
	100.29	100.10	99.82	100.04	100.06	100.00	(92.3)

1. Analysis by J. S. Long.
2. Analysis by Louis H. Koch.
3, 4. Analysis by the writer.
5. Average of the preceding, united Fe_2O_3 and Mn_2O_3, which are evidently isomorphous.
6. Same, corrected by removing the SiO_2 and recalculating to 100°. Ratios, $R_2O_3:P_2O_5:H_2O = 1.82:1:3.47$.
7. Partial analysis of the associated psilomelane, by Mr. Long. Alkalies and alkaline earths present but not determined.

CACOXENITE ($Fe_4(OH)_6(PO_4)_2.9H_2O$)

The locality which has yielded wavellite and beraunite specimens also has furnished beautiful small golden-yellow acicular crystals of cacoxenite.

AUTUNITE (Hydrous phosphate of uranium and calcium)

George W. Gehman, who has made a more careful study of the Easton minerals than anyone else, reports the presence of autunite in Williams' quarry which "fluoresces beautifully under the ultra-violet light."

URANATES

THORIANITE (ThO_2,UO_3,UO_2,PbO,etc.)

Mr. Gehman discovered a dark uranium mineral in the serpentine of Williams' quarry several years ago. Later he found similar materials in a quarry along Bushkill Creek and in an excavation for a reservoir along the south side of Chestnut Hill between the other two localities. He named it uraninite (pitchblende). Later he sent specimens to the U. S. Geological Survey where it was studied by R. C. Wells, J. G. Fairchild and C. S. Ross.[73] Analysis showed the mineral to contain so much thorium that it was identified as thorianite, a rare mineral not positively known to occur elsewhere in the United States.

Portions of this paper are quoted.

The larger masses of radioactive mineral showed little apparent alteration and were black and opaque, both in the hand specimens and in a fine powder, even when examined under the microscope. The largest crystals were cubes nine millimeters on a side. The specimens containing this black mineral were tested on a photographic plate and thereby the radioactive mineral distinguished from the associated dark colored hornblende, tourmaline, etc. The sample analyzed was separated from the associated mica, etc., by means of methylene iodide and analyzed in duplicate, following

[73] Amer. Jour. Sci., 5th ser., vol. 26, pp. 45-54, 1933.

closely the methods outlined by Fenner. The results are shown in Table I, columns 1 and 2. Under 3 is given the analysis of an alteration product, to be presently described.

A microscopic examination of the analyzed material indicated that the essential mineral was black, opaque thorianite, but a small proportion of a yellow to yellow-brown alteration product which had formed along fracture planes in the thorianite was present, and a very little rock material. The alteration product was isotropic and the index of refraction variable, with an average value near 1.72. The color and isotropic character is similar to the gummite, but the index of refraction is much higher. The mineral identity is not clear, but it is probably closely related to gummite.

TABLE I

Analyses of thorianite and derived gummite, its alteration product, from Easton, Pa.

[By J. G. Fairchild]

	Thorianite 1	Thorianite 2	Average	Gummite 3
UO_2	4.44	——	4.44	——
UO_3	33.15	——	33.15	——
U_3O_8	(37.14)	(36.62)*	——	42.70
ThO_2	38.53	38.41	38.47	25.06
PbO	5.33	5.08	5.21	3.86
Rare earths	2.49	(2.28)*	2.49	5.10
R_2O_3	1.57	——	1.57	——
CaO	.97	——	.97	——
MgO	.53	——	.53	——
MnO	.31	——	.31	——
H_2O+	4.82	——	4.39	——
Insoluble, including SiO_2	7.97	7.74	7.86	5.90
Total	99.66		99.39	
Specific gravity	6.68	——	6.68	——
Pb	4.96	4.72	4.84	3.58
U	31.50	31.05	31.50	36.21
Th	33.87	33.75	33.81	22.03

* Probably slightly low and not used in the average. (pp. 49-50)

Geologic age. The ratios between lead and uranium and thorium based on the analyses given in Table I are as follows:

TABLE II

	1	2	Mean of 1 and 2	3
Pb/U + .36 Th	.113	.108	.111	.081
Age (million years)	810	770	790	590

The ages were calculated by the equation

$$\text{Age, years} = \frac{\log [U + .36Th + 1.155\ Pb] - \log [U + .36Th]}{6.6 \times 10^{11}}$$

The brown mineral was clearly an alteration product of the black and so little weight is attached to the lower age based on the analysis of that mineral. The older age (calculation based on analysis 1 and 2) places the mineral as distinctly pre-Cambrian.

THORIUM GUMMITE (Thorogummite(?) (Uranium, thorium, lead, etc.)

This alteration uranium-thorium mineral found in association with the thorianite is described in the quotation above.

CARNOTITE (Vanadate of potassium and uranium with small amount of radium)

Wells, Fairchild and Ross in their article identified a mineral found in association with the thorianite and gummite as carnotite.

> The lemon-yellow coatings in fracture planes in the serpentine form radial groups of flattened blade-like crystals whose optical properties identify them as carnotite. The color under the microscope is pale lemon-yellow, and the extinction is parallel . . . The identity of the carnotite was also confirmed by a chemical test for vanadium, as a drop of concentrated HCl turned the yellow crystals a momentary blood-red color. (p. 53.)

SULPHATES

BARITE ($BaSO_4$)

Eyerman[74] reports the presence of barite in Chestnut Hill, Easton, as a rare mineral. Gehman reports a pink variety at this place.

CELESTITE ($SrSO_4$)

Eyerman lists celestite as one of the Easton minerals, but gives no descriptions.

GYPSUM ($CaSO_4.2H_2O$)

In the same list containing barite and celestite, Eyerman mentions gypsum as a rare mineral in the Easton serpentine locality.

MOLYBDATE

WULFENITE ($PbMoO_4$)

George W. Gehman reports finding wulfenite in the Easton serpentine quarries.

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[74] American Geologist, vol. 34, p. 45.

GEOLOGIC HISTORY

By Benjamin L. Miller

More than a billion years of history is recorded in the rocks of Northampton County and it is the duty of the geologists to decipher these records. The task is a tremendous one and is at present only in the preliminary stage. Many of the main events are dimly understood, especially those concerned with great upheavals or revolutions, but there are great gaps in our knowledge. The untangling of happenings in the dim past is made difficult and in some instances impossible by the destruction of much of the record. One may liken the work of the geologist to that of the historian who endeavors to write a consecutive history of mankind from a badly mutilated volume. If he can find in some other library another copy of the same book, perchance the missing portions of one volume will be found in the other one. By gradually extending his researches to other libraries where imperfect copies are preserved, eventually the gaps may be lessened and the story pieced together. Geologists work in a similar manner. Gaps in the recorded history existing in one locality may be filled in by data secured in another region.

Nature has been engaged alternately in construction and destruction; records have been written in the rocks and later in large part erased by the natural agents of weathering, erosion and metamorphism. Some records are transcribed in a language that is unintelligible except by the slow process of trial and error. An interpretation that seems reasonable at one period may be relegated to the discard when additional facts are obtained. Scientists have been accused of inconsistency when, without being conscious of any "loss of face," they throw aside their earlier explanations and advance new ones. Lesley expressed the idea in the following sentence.[75] "Geologists should be consistent; but what can poor geologists do when Nature is the mother of inconsistency." Little progress can be made unless interpretations (hypotheses and theories) are formulated to explain the facts accumulated. These are then tested by all the additional information that can be secured. Thus, the explanation may be strengthened, modified or thrown aside for a newer and better interpretation. Only in this manner have our natural sciences advanced.

The methods used by the geologist are those that have developed during the past century. By studying the natural processes of destruction and construction, and observing their effects and results, keys for deciphering the events recorded in the rocks and in the structural and physiographic features have been obtained. In the story of past events in this region, only the barest outline can be presented at this time. Gaps will be filled by future workers.

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[75] Lesley, J. P., Second Geol. Survey of Pennsylvania, Final Rept., vol. 2, p. 891.

Pre-Cambrian History

By Donald M. Fraser

With the assumption that the Franklin limestone is the oldest formation in the district, the earliest recorded event in Northampton County would be the deposition of a series of carbonate rocks. Little else is known regarding this earliest time. Following the accumulation of the limestone, or possibly more or less contemporaneously with it, clastic sediments containing carbonaceous material were deposited. The present quartz-graphite member of the Franklin formation is the remnant of this depositional period which surely resulted in a fairly extensive sedimentary formation at the time of its accumulation.

With the changing conditions of deposition the sediments from which the present Moravian Heights formation has been derived were laid down. These were quartzose sediments but were more argillaceous than the clastic material associated with the Franklin formation. Again, on the basis of the present distribution of small areas of the Moravian Heights throughout tens of square miles, it is assumed that the original sediments were of considerable extent. They may well have covered several hundred square miles.

The next formation is the Pochuck gneiss. This basic rock, in the past, has been considered as of possible partial sedimentary origin and in part to have been derived from the metamorphism of a gabbro or diorite-gabbro type of igneous material. The present writer regards the Pochuck of Northampton County to be entirely of igneous origin. It may have been formed by the metamorphism of a gabbroic type of rock but it could also have been derived from the metamorphism of a series of andesite and basalt lava flows. Whichever may prove to be the correct interpretation, the next event in the district following the accumulation of the Franklin and Moravian Heights sedimentary formations was igneous activity. Either the present Pochuck gneiss material was introduced by intrusions of a basic magma or by the extravasation of lavas.

The earliest of these three formations has been tentatively assigned to Archean time and the later two to the Huronian. They are all of patchy occurrence and with the exception of the Pochuck have very small areal extent.

Later Proterozoic time probably saw extensive erosion and igneous invasion of an acid type of magma. The group of rocks known as the Byram gneiss ranges from what is considered to be typical Byram (a quartz-microcline microperthite rock) to quartz monzonite types.

Associated with these are numerous pegmatites. The entire series has been mapped as Byram because more detailed study and mapping than that possible on the scale of the map used here, will be necessary to delineate the various facies. In the sequence of pre-Cambrian events, therefore, we are able to state only that during later Proterozoic time extensive granitic intrusion prevailed in the area under discussion. That this intrusion was in part deep-seated is evidenced by the highly irregular and injected and contorted nature of the contact between the Byram and Pochuck. It follows, therefore, that after the granitic invasion there was very extensive erosion before the surface upon which the Cambrian rocks were deposited could have been exposed. Proterozoic magmatic activity continued into early Paleozoic time or repeated invasions of magmatic material may be suggested with the later activity continuing into at least Lower Paleozoic time. The evidence for this is the occurrence of quartz-feldspar dikes in the Hardyston sandstone near its contact with the pre-Cambrian granitic material. With the dying stages of magmatic action existent into Lower Paleozoic time, at least some of the quartz veins found in the Cambrian and Ordovician rocks may well be of magmatic origin.

Cambro-Ordovician History

The Paleozoic history of this section recorded in the rocks begins with the deposition of the Hardyston sandstone in the Lower Cambrian period. There is, however, a big gap between these deposits and the underlying crystalline rocks of the pre-Cambrian.

The Hardyston sandstones, wherever contacts have been observed, rest unconformably upon greatly metamorphosed gneisses. An examination of these basal rocks shows that they attained their present character of coarse-grained and banded crystalline rocks while deeply buried beneath enormous loads of other rocks. The Byram gneiss, which is the most common type of rock on which the Hardyston rests, was originally a granite and it is now generally recognized that granites are igneous rocks that cooled at considerable depth beneath the surface. The gneissic banding, which the Byram shows, is believed to have been developed as the result of subsequent excessive compression and resultant heating such as can also take place only at great depth. These features must have been acquired long before the Hardyston strata were laid down since these deposits show positively that they have never been subjected to such metamorphic agencies. The conclusion, therefore, seems certain that a long period of erosion, during which a great thickness of pre-Cambrian rocks was removed, preceded the opening of Cambrian deposition. One can only guess at the depth of surface rocks carried away but it appeals to the writer that the amount was upwards of a thousand feet and probably

several thousand feet. It is pure conjecture as to where the eroded material was transported and deposited as no evidence bearing on this problem is now known. Here, therefore, is one of the great gaps in our history of past events in the region.

The earliest recorded event in the Paleozoic history of the district is the depression of the entire region as well as extensive areas both to the northeast and southwest. The entire Appalachian region, which had presumably long been an area of erosion, gradually sank beneath the waters of a great southeasterly advancing inland sea.

Beginning with Hardyston time and continuing throughout the entire Paleozoic era, all geologists believe there was a large continental land mass, to which the name "Appalachia" has been applied, from 100 to 300 miles or even more in width, that paralleled the present Atlantic shore line. At times the northwest margin of this land perhaps lay only a short distance to the southeast of what now constitutes Northampton County. At other times, the shore may have been several scores of miles away.

The inland sea covered all of the present Appalachian province. It varied from time to time in size and shape owing to movements or warpings of the earth's crust. In this sea, which appears to have always been comparatively shallow, practically all the materials now constituting the sedimentary rocks of Northampton County were accumulated on a gradually sinking bottom.

When the depression of the area occurred, there was probably a fairly deep cover of soil and rotten rock over the land. The waves of the advancing Cambrian sea seem to have removed most of this surficial cover inasmuch as the Hardyston in most places rests on fresh unchanged gneisses. Locally, however, a thin band of a peculiar rock is found at the contact, which is believed to be an old soil. It has now been altered to a dense, fine-grained, light green rock that has been called pinite. It is never more than a few feet thick and can seldom be recognized over any extensive area. It is developed in very few localities in Northampton County but in the adjoining area of Lehigh County it is better known. It is questionable as to whether this material should be included in the Byram or in the Hardyston. Inclusions of angular vein quartz fragments link it with the former, and occasional rounded pebbles suggest the latter reference.

The lowest strata of the Hardyston are conglomeratic in several places but not everywhere; occasional pebbles are more than an inch in diameter. These coarser sediments constitute a basal conglomerate that was formed either near the mouths of streams or where shore currents were reasonably strong. They probably formed near the shore as the advancing sea transgressed. They also indicate that the land

mass from whence the pebbles were derived was fairly high and thus furnished stream gradients sufficiently steep to transport the pebbles.

Probably owing to the southeasterly retreat of the shore line by the sinking of Appalachia, coarse pebbles were carried into this region for only a short time. Most of the deposits of Hardyston time were sands, generally fairly fine. Crystalline rocks from Appalachia were breaking up without the complete decomposition of the feldspars, and numerous grains of fresh orthoclase were deposited with the quartz grains and kaolin. The arkosic character is a prominent feature of the Hardyston sandstones.

A progressive change in the sediments from sands to shales and calcareous oozes took place and we pass from the Hardyston to the Tomstown sediments. The Tomstown and also the overlying Allentown formations contain occasional fine sandstone lenses, indicating that unusual conditions, probably freshets or floods, once in a great while brought some sands into the region. Generally, however, only the finest land-derived material came in. This indicates the lowering of Appalachia to the extent that the streams entering the sea carried only the finest material in suspension and these only at certain times. They brought calcareous matter in solution and this was precipitated on the ocean bottom either by purely chemical processes or by the agency of minute organisms, particularly bacteria. Probably both methods were operative. The rocks themselves present no evidence as to the method by which the calcareous matter was taken out of solution.

During Allentown time, less sand and mud entered the sea although shaly layers and a few fine sandstone lenses indicate that occasionally terrigneous matter came into the sea from Appalachia. The life of the Allentown seas was not varied, so far as local evidence indicates. The only abundant fossils are the calcareous algae, *Cryptozoa,* which are fairly abundant. In places they withdrew from the sea water and built into their structures sufficient calcareous matter to form deposits several feet in thickness.

Occasionally during both Tomstown and Allentown time the sea was so shallow that at low water, perhaps low tide, the fine muds were exposed to the drying action of the sun and developed mud cracks as they contracted in drying. These are preserved in many localities. Ripple marks and oolites also indicate shallow water.

When the deposits of the Tomstown and Allentown formations were accumulating, the oozes contained much magnesia, and these limestones are prevailingly dolomitic. In part the magnesia may be secondary but it is regarded as largely original.

In the succeeding interval of time, when the Beekmantown limestones were formed, the calcareous oozes at times contained very small quantities of $MgCO_3$ and we therefore have in this formation the alternations of high- and low-magnesian strata.

Throughout Tomstown and Allentown time the seas had been generally clear of land-derived sediment except at occasional brief periods. The Beekmantown sea was even clearer and mud seldom came into it. This probably means that Appalachia was so low as to yield to the sluggish streams a minimum amount of mud in suspension and practically none of it was carried into this region. An alternative interpretation is that the nearest land mass was more distant.

Shell-fish were more abundant during the Beekmantown but, as indicated by the rarity of fossils, relatively sparse in this section, especially as compared with some other regions in the Appalachians.

Following the formation of the Beekmantown there was a short break in deposition, as shown by an unconformity between the Jacksonburg and the Beekmantown. Deposition was resumed and the seas became increasingly muddy and the $MgCO_3$ decreased. The interval represented by the deposition of the lower member of the Jacksonburg formation was a time when high-calcium oozes accumulated. It was followed by the deposition of much terrigenous mud which was mixed with the calcareous oozes. These constitute the upper member of the Jacksonburg. These argillaceous low-magnesian limestones are the most valuable deposits of the county, as they have furnished the material for the extensive portland cement industry of this region.

Fossils are much more abundant in the Jacksonburg than in any of the other sediments of the region, thus indicating more favorable conditions for life and growth. The animals seem to have been mainly near-shore forms and their skeletons were broken by wave action to such an extent that the fossils are mainly fragments. Crinoids were abundant but only the disarticulated plates are preserved.

Increasing muddiness of the seas and the practical disappearance of calcareous precipitates resulted in the deposition of the argillaceous Martinsburg strata. Carbonaceous matter is abundant in these dark gray or black sediments. Its source is problematical but may have been marine plants. Graptolites may have contributed part of the carbonaceous content. Frequent changes in the character of the sediments has resulted in the production of the light and dark layers that are called ribbons by the slate operators. These are most prominent in the lowest member of the Martinsburg.

The middle (upper according to one view) member represents a period during which considerable sand entered the sea in this section.

Likewise, more calcareous matter was precipitated and these sandstones, when fresh, effervesce freely when hydrochloric acid is applied.

For about 200 million years, from early Cambrian to Upper Ordovician, deposition had been going on almost continuously in this region, and sediments had accumulated to a thickness of 7,500 to 10,000 feet. The continent of Appalachia and the inland sea underwent modification many times but there were few breaks in the process of deposition. A minor one occurred at the close of the Beekmantown. In New Jersey there appears to have been a more decided interruption than in Northampton County.

Taconic Disturbance [76]

After Martinsburg deposition there was a marked disturbance in this region, so great that it has sometimes been called the Taconic Revolution. It is named from the Taconic Mountains of western Massachusetts where it was first studied. How much of the complex folding and faulting of this region is due to this period of compression and uplift and how much was produced by later movements of the Appalachian Revolution is still a matter of argument and discussion. The writer holds the belief that a large part, perhaps the major portion of the rock folding of this region, was produced at the close of the Ordovician. He is inclined to the belief that the slaty cleavage of the Martinsburg was chiefly produced at this time. The pressure seems to have come from the southeast.

A period of erosion followed the disturbance but the amount of material then removed can not be determined with any accuracy. Stose[77] believes that the Taconic movements and the erosion following were so profound that all the middle (upper of Stose) member of the Martinsburg was removed by erosion so that the next deposits to be formed were laid down on the lower Martinsburg member. The writer does not accept this view.

Silurian and Later Paleozoic History

After a marked erosion period, during which time all of the Northampton County area was above water, the region again sank beneath the waters of the vast inland sea. The deposits then made constitute the Shawangunk conglomerates and sandstones that form the northern boundary of the county. The basal conglomerate layer exposed in Lehigh Gap rests unformably upon the eroded edges of the Martinsburg slates. There is a difference of thirteen degrees between the bedding planes of the two formations.

[76] Miller, B. L., Taconic Folding in Pennsylvania: Geol. Soc. Am. Bull., vol. 37, pp. 497-511.
[77] Stose, G. W., Geol. Soc. Am. Bull., vol. 41, pp. 629-658.

The coarse pebbles of the Shawangunk, many more than an inch in diameter, furnish evidence of strong currents and probably steep slopes of the land mass to the southeast that furnished the material.

Later sedimentary Paleozoic history is not preserved in Northampton County although it is probable that some and perhaps all of the later Silurian, Devonian, Mississippian and Pennsylvanian formations exposed in the regions to the northwest in neighboring counties may have once extended into this county. If so, they have been entirely removed by subsequent erosion.

Appalachian Revolution

The Paleozoic era in the Appalachian region ended by one of the most profound periods of uplift, folding and faulting that has ever taken place. Thousands of feet of rocks were folded by compressive forces coming from the southeast as though they were mere sheets of paper. These movements, added to those that deformed the earlier strata at the close of the Ordovician, made the complex and baffling structures so characteristic of Northampton County.

Triassic History

The only record of events of the Northampton County area during the Triassic period is found in Flint Hill, a small sector of which is contained in the most southerly corner of the county. The prevailingly red shales and conglomerates found there are part of a great series of deposits formed in bays, low-lying valleys or estuaries that extend from Massachusetts to North Carolina. The deposits may have extended somewhat farther north of the present limits at one time.

Glacial History

In the Pleistocene period this region was invaded by a lobe of the great ice sheet that originated in eastern Canada. Although the erosional and depositional work of the ice profoundly modified much of the New York and New England regions, this section reveals few evidences of its work. It passed through the valley, probably covering practically all the area between Kittatiny (Blue) Mountain and South Mountain, with a slight advance into the Saucon Valley. The ice in this advance seems to have been thin so that the amount of erosion was trivial. Deposition throughout most of the county was of little consequence except in some depressions, such as old stream valleys and solution holes in the limestones.

The only decided changes in the topography are in the belt of the terminal moraine, Belvidere-Pen Argyl region. Here there are many low irregular hills entirely composed of glacial debris.

Whether the deposits formed during the greatest advance of the ice should be considered as belonging to the Illinoian Ice Sheet or the preliminary advance of the Wisconsin Ice Sheet is a problem that has long been in question and is discussed elsewhere. The terminal moraine represents either the greatest advance of the Wisconsin or a halting period before its retreat from the region.

Physiographic History

The physiographic record has been discussed in the chapter on Physiography, so only a brief summary is given here.

The existing topography is the result of erosion and minor deposition with alternate peneplanations and uplifts that have been at work in this region ever since the Appalachian Revolution. Decomposition, rain wash and streams have been the tools with which Nature has carved the existing hills and valleys.

Presumably, the period of Schooley peneplanation in Tertiary time saw the entire area reduced to a featureless low-lying region with all elevations due to earlier earth movements destroyed. From this surface the present differences in elevation have been developed, following an uplift that revived the agents of erosion. Those areas with the most resistant rocks, such as the siliceous sandstones of Kittatinny (Blue) Mountain, have suffered least and now stand highest, whereas the softer and more soluble rocks, such as the limestones, constitute our valleys.

If this region maintains its present elevation with reference to sea level, the destructive processes of erosion will continue to modify the topography. The tendency will be to reduce the existing differences and produce even more subdued scenery, with the ultimate reduction to another base level plain. Under present conditions this may result in from one to three million years. From what we know of the earth's instability, one may well question whether before that time there may not be interruptions or modifications in the erosive process caused by deformations of the crust.

INDUSTRIAL DEVELOPMENT

By Benjamin L. Miller

The Lehigh Valley at the present time is generally rated as primarily an industrial region. The industries are varied and valuable. Into the region are continually coming raw products and minor manufactures from the far ends of the earth and from it are going other manufactured articles to various parts of this country and to foreign countries far and near.

The importance of the present topography and geology can scarcely be exaggerated, and numerous illustrations of their relation to our many thriving industries of today could be cited. The great thickness of limestones and shales has resulted in the open valley where agricultural pursuits can be carried on. The valley of the Lehigh made possible the building of the Lehigh Canal and facilitated the construction of the major railroad lines. The gaps in the mountains cut by the streams are more numerous than in some sections and have aided in the construction of highways. Although other factors than topography determine the location of cities and villages, it is readily recognized that comparatively flat land, such as prevails in most portions of the lower Lehigh Valley, has had a marked influence in the location and growth of the settlements and the establishment of many of the existing industries.

The climate, soils and water resources are all important factors in the industrial development of any region and have been discussed elsewhere in this volume.

Man-Made Advantages of the Region

Before discusing the different industries, we may point out the common man-made advantages of the region. The main advantages are summarized as follows:

Proximity of markets.—With a population of approximately 500,000 within the Lehigh Valley and more than 17,000,000 within 100 miles of Bethlehem and 26,000,000 within 200 miles, a distance that a truck can easily go in a day, the strategic location of the Lehigh Valley for markets is apparent.

Transportation.—Road building received attention at a very early date. Dirt roads prevailed during the early years of settlement and were almost impassable during certain seasons, yet they facilitated exchange of products. The next stage was the building of privately owned hard-surfaced cobblestone turnpikes with their familiar toll

gates and toll bridges. Recent State roads of macadam or concrete construction are too familiar to need especial attention. As one community after another is provided with year-round improved roads, every industry of the region is aided.

The first great advance in large-scale transportation was the opening of the Lehigh Canal in 1829. This waterway afforded ready transport of anthracite to Philadelphia and developed the coal industry on which so many other industries depend. Several years previously, coal had been shipped on flatboats down the Lehigh and Delaware rivers but as the boats could not be brought back the quantity shipped was very small.

The building of the railroads in the 1850's and later marked a still more profound advance. The Lehigh Valley Railroad from Easton to Mauch Chunk was completed and began operation in 1855 and stimulated all the industries along its line. As each additional railroad or branch was built, the industries already established were able to expand and new industries were attracted.

The transit companies starting in 1865 were first confined to the larger boroughs but gradually were extended until they connected most of them. Owing to the recent building of hard roads, the tracks of the once valuable inter-urban transit lines are being torn up and trucks and buses are being substituted. It is difficult to foresee the future solution of the changing traffic situation.

Although the present transportation facilities leave much to be desired, they are reasonably adequate for the industries of the valley. No section of the region is ever isolated for more than a few hours even in the most inclement weather, and products can quickly and easily reach the large cities of the Atlantic seaboard. Improvements are being made and no doubt will continue.

Labor.—The region has attracted industries because of both adequate and efficient labor and, in general, the freedom from labor disputes. For many years the expanding industries gave opportunity for an ever-increasing number of European immigrants. Of course at present there is a vast surplus of both skilled and unskilled laborers but all hope and trust that this condition is only temporary. The region has been a melting pot. Here one sees the results of Americanization where the first generation consisted mainly of unskilled labor, and the second and third generations furnish their fair share of skilled labor.

The immigration of the first 150 years was largely from countries of northern Europe, particularly Germany and the British Isles, whereas in the last 50 years most immigrants have come from Italy

and the Balkan states. Negro labor has never been an important factor in the valley.

Electric power.—A community's ability to produce wealth in our modern economic system is measured by the amount of power at the worker's command. An estimate based on available figures shows that the average worker in the Lehigh Valley commands about six horsepower, mostly in the form of electric motors. The industrial expansion of the region could not have come without an adequate and reliable supply of electric power.

Twenty years ago (1918-1920) electric power sources in this region were scattered, uncoordinated, unreliable and inefficient, judged by modern standards. The larger industries and municipalities generated electricity for local consumption only. The electrical transmission of power as we know it today was virtually non-existant. Before 1920 the only high-voltage transmission lines in eastern Pennsylvania were the 110,000-volt lines of the Lehigh Navigation Electric Power Company from Hauto to Siegfried and from Siegfried to the Bethlehem Steel Company's quarry.

Since the World War the electric power demand of the region has been increased 500 percent. The scattered sources have been tied together into an integrated system of 850 miles of high-voltage transmission lines. Small inefficient generating stations have largely disappeared and have been replaced by a few large steam-electric stations totaling nearly 400,000 kw capacity, and one 400,000 kw hydro-electric station.

Inter-relationship of the industries.—In the complex industrial situation of the present, the location of one industry in a region favors the building of plants in allied or dependent lines. Many examples of this kind might be cited. Another important factor is the connection of heavy industries requiring men, with other industries employing many women. Silk and tobacco manufactories are commonly located in proximity to mines and manufacturing establishments employing mainly male labor.

Survey of the Major Industries

Within the limits of this article it is manifestly impossible to present a detailed or adequate picture of the numerous and varied industries located here. The products of a single firm may be so numerous and varied as to surprise almost anyone not closely connected with the organization. A mere enumeration of the products of

the manufacturing plants located here has never been attempted. It might be enlightening but would be of only temporary value because of the constant changes.

The first settlers engaged almost exclusively in the cultivation of the soil. It was not long, however, before manufacturing was established. The Moravian settlement at Bethlehem at a very early period undertook to make themselves independent. In the division of labor, masons, carpenters, weavers, spinners, millers, potters, and farmers were engaged in their special lines. In 1754, 13 years after the founding of Bethlehem, 60 industries were being carried on in the community, with iron bars almost the only product imported.

Agriculture.—In all communities in which the basis of settlement is the search for freedom, agricultural interests are in the beginning the chief concern. Grains must be grown as quickly as possible. Game was plentiful in the Lehigh Valley when the first settlers arrived and the streams were well stocked with fish. Crops were quickly planted. Wheat, corn, rye and potatoes were grown for food and flax was planted to supply material for clothes. At an Indian settlement just north of the present borough of Nazareth peaches and apples were being grown and these fruits were extended to the new settlements of the whites. In a comparatively short time the settlers made themselves fairly independent so far as food was concerned, and the excess grains and hides were hauled to Philadelphia where other necessary commodities were obtained.

The earliest settlements were made in the limestone valleys and along the streams where the soil was rich and the fairly level topography appealed to the farmers. With the rapid influx of population, the more rugged country was occupied.

For the past 150 years there has been little idle land in the lower part of the Lehigh Valley except in limited areas of steep slopes. In the upper part of the Valley where the best forests were found and where the stony character of the soil interferes with cultivation, rather large areas have never been under cultivation.

For a long time the principal crops were wheat, corn, oats, rye, barley, timothy, clover, and alfalfa. When the central states became a great granary and the prices of grain were lowered it gradually became evident that the growing of potatoes, especially in the shale areas where the soil is particularly suitable, was more profitable than grain. For many years the potato crop of certain sections has greatly exceeded the grain crops in value.

As the population of the Valley increased and the transportation facilities were improved, demand increased for perishable products, such as vegetables and berries, which now constitute a large part of the farm income.

Cattle, horses, hogs, sheep and poultry have been raised on most of the farms, but, with the exception of poultry, have seldom constituted the major interests of many farmers.

The growing of fruit was, until recent years, a minor activity. Practically every farmer had an apple orchard for his own use as well as a few cherry, peach, pear and plum trees. These were given little attention and produced an indifferent quality of fruit and variable yield. With appearance of the scale insect, the fruit trees died unless sprayed and in many cases the cost of spraying seemed prohibitive. A new era of fruit growing has developed in recent years, one which promises extremely satisfactory results.

Another farm industry that has grown greatly in recent years is dairying. From the beginning each farmer possessed a few cows to supply the family with milk and butter. Surplus supplies were marketed and with the sale of eggs and chickens helped to pay the store bills.

A unique agricultural industry of Northampton County is the production of dehydrated alfalfa meal by the Green Acre Farms near Nazareth. The production is about 6,000 tons per year. It is shipped all over the eastern part of the country.

Food and Beverage Industries.—Because of the close connection of the food industries with agriculture, they are discussed at this point. It is well recognized that, at the present time, the food industries of the region are not confined to the food materials produced in the region, yet at one time they were largely so. With the exception of sugar, salt and some other commodities the early settlers produced their entire food supplies. How greatly changed is the present situation! Articles of the daily food of our table are brought to us from the most remote portions of our own country and from many foreign countries.

Flour mills.—During the Revolution War the Lehigh Valley was called the granary of Washington's army. The wheat grown in the Valley was ground into flour by the water-power mills along the creeks and hauled in wagons to Valley Forge. These small mills were valuable assets of the region for the first century of settlement, since which time their importance has dwindled. Some of these are still in operation although most are in ruins. Larger and more efficient units have taken their place.

The largest milling company in the Lehigh Valley and also the largest in the State is the Mauser Milling Co. with one plant at Northampton and others in Lehigh County. The company has a daily output of 1,000 barrels of flour made from Pennsylvania winter wheat, and spring wheat from the Northwest. The Flory Milling Co., Inc., of Bangor, is a long-established firm with an excellent reputation.

Bakeries.—The art of bread-making was at one time regarded as one of the most necessary qualifications for the housewife, and bakery bread was a luxury in certain homes and completely tabooed in others, largely due to the skill of the domestic cook. Within a few decades all this has changed so that now the bakeries constitute one of the largest food industries of the Valley. The substitution of bakery products for home-cooked products has been brought about by the superior quality as well as reasoanable prices for the bakery output. There are numerous bakeries but naturally they cannot be separately named and described.

Pretzels are made in many communities. The products are consumed in large quantities locally and also shipped to other sections.

Ice cream.—The ice cream industry of the county dates back to 1858 when Herman S. Grosh began manufacturing it in Bethlehem. There have been many improvements and scores of concerns engaged in the business since then. Some of the brands have become noted for their quality. Abel's ice cream made in Easton was long justly famous. Many of the local companies have been absorbed by large corporations located outside the region that use the local plants merely as distributing centers.

Beverages.—In the early days there were many distilleries along the streams, and hard liquor was consumed in quantity. These small concerns have been superseded by large establishments engaged in the production of beer, ale and porter and soft drinks. During the days of prohibition some of the breweries closed their doors and others engaged in the manufacture of soft drinks. Since the repeal of the prohibition amendment the breweries have been overhauled, in some cases enlarged, and the industry re-established.

One brewery is responsible for the statement that "the general trend of the brewing industry today is to establish beer on the basis of a food rather than an intoxicating beverage, and legitimate brewers are backing this policy to their utmost. Among the newer developments in the brewing industry can be listed the canning of beer and the adding of vitamins."

Mining and quarrying.—Pennsylvania has long held supremacy over all the other states of the Union in its mineral wealth. It has often been stated that the development of coal and iron ore laid the foundation for the industrial development of Pennsylvania. In Northampton County the presence of iron ore, ceemnt rock and slate have been of the greatest importance.

Iron and steel.—The earliest mining and smelting of iron ore in the region took place at Durham Furnace, Bucks Co., near Riegelsville, a few miles from the Northampton County line, in 1727, the date at which the first blast furnace was erected. A bloomery may have been operated there even earlier. The iron ore, magnetite, was obtained from Rattlesnake and Mine hills nearby; the limestone for flux was quarried at several places within a quarter of a mile; and the charcoal for fuel was obtained from numerous residents who cut and burned the wood growing on the hillside. The products were mostly pig iron, pots, kettles, and fire backs. Three forges for the manufacture of wrought iron were located in the same vicinity. Durham Furnace was operated about two-thirds of the time from 1727 to 1908, a period of 181 years.

Iron mining did not extend to Northampton County until the beginning of the 19th century. One of the earliest operations was a forge built on the Bushkill Creek about 2 miles northeast of Nazareth in 1808 by William Henry. The iron ore presumably was mined near Nazareth. The iron was used in the manufacture of rifles and shotguns.

For the next few years the iron ores apparently received little attention. Beginning about 1825 the prospecting and opening of iron mines became active and was carried on over much of the county until about 1910, a period of 85 years. The mines are widely scattered throughout the limestones of the Valley and in the sandstones on the slopes of South Mountain. The exact number of deposits worked is not known but 89 places are marked on the county map. Some of them furnished only small quantities but others yielded as much as 100,000 tons. The ore was of variable quality and a constant supply could not be depended on as many deposits were worked only when farm labor was slack.

Furnaces were erected at numerous points; a string of them followed the Lehigh River in Carbon, Lehigh and Northampton counties—Parryville, Hokendauqua, Catasauqua, Allentown, South Allentown, Bethlehem, Freemansburg, Redington, Glendon and South Easton. Others were at Hellertown, Bingen, Em(m)aus and Alburtis.

As transportation facilities improved, iron ore of higher grade and more uniform quality came into the region from northern New Jersey, eastern New York and Michigan. The local mines could not compete and gradually one after another closed until all are now abandoned. Most of the furnaces continued to operate on imported ores for a while but they too got into difficulty and one after another they disappeared. The immense piles of slag through the region, some of which is now being used as road ballast and for concrete, bear witness to the former wide distribution of the iron industry.

The Bethlehem Steel Co. is the outgrowth of a small iron company such as many others that formerly dotted the section. The original company was the Saucon Iron Co., incorporated in 1857. The charter of the present company dates from 1904. Its growth in the past 30 years was rapid and steady until the present depression. It is the largest industrial plant in the Lehigh Valley and its importance to the community and the country at large can scarcely be over-emphasized. The products emanating from this establishment are marketed over the entire world. During the World War the company was almost entirely engaged in the manufacture of war materials and at all times it has furnished the U. S. Government with many products. To enumerate its present products is not desirable but it may be well to call attention to some of the leading products such as structural steel, various alloys, merchant bars, forgings and castings, tool steel, and machine products.

Giving employment to thousands of men and using annually 1,250,000 tons of coal and large quantities of electrical power, one can well appreciate its outstanding importance in the Lehigh Valley.

The region also contains a variety of manufactures in which iron and steel play a large part. The Treadwell Engineering Co. of Easton that manufactures cars for hot metal and cinders and heavy steel plant machinery; the Pennsylvania Pump and Compressor Co. of Easton manufactures a long line of compressors, pumps and condensers; the Bethlehem Foundry and Machine Co. of Bethlehem manufactures machines used in the cement, chemical and metallurgical industries; and many others.

At times other metal concerns have been active in the county but have passed out of existence with changes in the industrial life of the Nation or have gone into other lines of manufacture.

Limestones.—As described on earlier pages, Northampton County is bountifully suppled with limestones. Although formerly quarried in scores of places for lime, flux, crushed stone and building stone, only a few operations of any considerable size have been developed. The abundance and wide distribution of limestone account partly for this situation.

The limestones, other than those used for cement manufacture, have contributed much to the economic development of the county but at the present are of lesser importance. For many special purposes it is advisable to bring in from other regions limestones of greater purity.

Cement.—The argillaceous limestones that outcrop in a band crossing the county from Northampton to Riverton, passing through Bath, Nazareth, Stockertown and Martins Creek, have contributed enormously to the wealth of the region. The cement plants in this belt are almost entirely responsible for the main growth and development of all of the towns mentioned. No other mineral product of the county has been used as extensively and so far as the supply of desirable stone is concerned the industry will long retain its important position.

Slate.—Nearly all the towns of the northern part of the county owe their location and growth to slate operations in their immediate vicinity. Until recently, scarcely a building of any kind could be seen in the region that did not have a slate roof. Slate has been produced for many other purposes. However, regardless of the fact that the region ranks first in the Nation, the local slate industry has had its ups and downs. It has prospered when building activity prevailed and suffered when depressions have curtailed building operations. The local industry is capable of a production far in excess of any demand thus far made as an almost unlimited supply of excellent material is available.

Minor mineral products.—Deposits of sand, gravel, clay, building stones, and mineral pigments have had no small part in the upbuilding of the region, although their use has almost always been extremely local.

Chemical Manufactures

The chemical manufacturing establishments in the region are many and varied. Some of these, such as lime, cement, iron and steel, clay products, mineral pigments and breweries, are separately discussed. There remain, however, a few to be briefly described here.

The first strictly chemical operation definitely recorded within the Lehigh Valley was the burning of lime for the Whitefield house in Nazareth and for the foundations of the first Moravian buildings in Bethlehem. Soap was made by the Moravians in the basement of the Sisters House within a short time after it was built, and both tanning and fulling (the tanning of soft or white leather) was done in Bethle-

hem within a few years after the coming of the first settlers. The virgin forests of the region contained many hemlocks, the bark of which was used in hides for many years. Bark was shipped in after all the local hemlocks had been cut. Old maps show the location of many tanneries throughout the Valley. Some of the tanners acquired considerable skill. One man is said to have developed a process that enabled him to take the hide from a calf in the morning and have a pair of boots by evening.

The Moravians manufactured some of their own drugs, and their first drug store was in the Bell House, and moved to its present location on Main Street, Bethlehem, in 1752. Dr. Adolph Meyer started a small garden of medicinal plants in 1742 or 1743, and his successor, Dr. John Frederick Otto, increased the size of the garden to several acres, and became a noted authority on medicinal plants and the drugs made from them. The garden first planted by Meyer and extended by Otto was the first purely medicinal garden in the United States. The drug store started by Otto in 1752 is still operated at its original location, and is generally credited as the earliest drug store in America that is still in existence.

The following account of the industries of this district, as they existed near the close of the 18th century, is taken from the notes of Dr. John Schöpf, who visited Bethlehem in either 1783 or 1784:

> We visited the interesting factories and mills belonging to the Society, and among these was a well arranged oil mill and grist mill. . . . There is besides a profitable tannery, with the requisite bark mill and an extensive dyeing establishment. . . . Near the river is an ingeniously arranged brewery. . . . The water used in the brewery is pumped from the Lehigh. The boiler is at such an elevation that the boiling water flows downward over the malt, and is thence pumped by hand into the vat that contains the hops, from here the infusion is drawn off in pipes leading to the cooling vat, and finally led by others into casks in the cellar immediately below, these arrangements under one or two men sufficed for all of the necessary work. The malt is dried in the air. The beer is of superior quality.

The making of candles and the manufacture of soap began on so small a scale that their beginnings are lost in obscurity. The manufacture of soap has continued in the region, although on a relatively small scale, down to the present time, and the manufacture of candles was a substantial industry in Bethlehem and other towns of the Valley down to the period when they were largely superseded by kerosene and later by gas and electricity. Wax candles for the Christmas season are still made in Bethlehem.

Vinegar was made in the Valley, and camphene (a burning fluid consisting of oil of turpentine and later of a mixture of turpentine and alcohol) was made in Easton by Semple & Bros. at an early date.

The region has made substantial contributions to chemical education, and many of the graduates of its colleges have brought credit to the Valley by their accomplishments. James Gayley, a student of Dr. T. M. Drown at Lafayette, is said to have been the first chemist employed in the iron and steel industry in the United States, and later became a Vice President of the United States Steel Corp. Dr. Porter W. Shimer and Dr. B. F. Fackenthal, Jr., were other early chemists and metallurgists of the Lehigh Valley who made substantial contributions to the application of chemistry to metallurgy at the critical period when the making of iron changed from an empirical to a chemical art. The many important contributions made to chemistry by the teachers and the graduates of the chemical courses of Lehigh University and Lafayette College are too well known to require repetition in this paper.

The establishment of the *American Chemist* in 1871 by Dr. Charles F. Chandler, then Professor of Chemistry at Lehigh University, greatly stimulated the interest in chemistry throughout this country, and was one of the important factors that led to the founding of the American Chemical Society in 1876. The Chemical Publishing Co. of Easton, Pa., has also contributed to the spreading and popularizing of a knowledge of chemistry throughout the country.

Textiles

The textile industry, from the earliest settlement, has been one of the extremely important industries of the county. Hemp was grown by the Moravians at Bethlehem at an early date and the flax was treated and woven by the residents. Wool from the local farms was woven into cloth by early settlers. Raw cotton has been shipped into the region for a cotton industry. Although the aggregate importance of the wool, linen and cotton industries of the region is great, they are so overshadowed by the silk business as to be relatively unimportant and cannot be adequately discussed here.

The silk industry of the region may be divided into several periods. The Moravians in Bethlehem and Nazareth at three different times started the growth of raw silk, influenced by the numerous mulberry trees in the region. The first experiment was in 1752, the second about 1793 and the third in 1837-39 when a widespread silk-growing craze swept over the country. These three early attempts were complete failures.

The present silk industry began about 50 years ago and has increased until it has become one of the most important industries of the whole region and in some years exceeds in value any other

industry. There are no cocooneries in the region or in the State. Owing to the great number of laborers required and the difficulty in raising the white mulberry trees, it has been found impossible to compete with China, Japan and Italy where there is an abundance of cheap labor. Therefore nearly all the silk produced today comes from China and Japan.

The silk industry began here by using real silk alone and some mills even yet confine their entire operation to the silkworm product. Many, however, have substituted wholly or in part the manufactured material, long known as "artificial silk" but now termed "rayon."

Pennsylvania is the largest silk and rayon manufacturing State in the country, with over 500 weaving, throwing and hosiery mills within its boundaries. This industry is the third largest industry in the State, manufacturing about 65 percent of all of the silk and 35 percent of all rayon consumed in the United States. There are about 250 mills in the Lehigh Valley (Northampton and neighboring counties) area, which is about half of the mills in the State. However, owing to the greater capacity of these mills, the Lehigh Valley makes about 75 percent of the total silk produced in Pennsylvania. Bethlehem and Easton rank high as silk-producing centers.

The principal reasons for the silk industry centering in the Lehigh Valley area and eastern Pennsylvania are steady, efficient labor, largely women, comparative freedom from labor troubles, cheap and reliable power, and proximity to New York where most of the raw silk is obtained, and the finished product is distributed.

Lumber and Lumber Products

The lumber industry started in the region about as early as any activity. Hewn logs were first used but it was not long until sawmills were built along the streams. Combination grist and sawmills were built in some localities.

The lower part of the Valley never produced much good lumber. At an early date pine logs from the region about or beyond Blue Mountain were floated down the Lehigh River for building houses in the lower part of the Valley. Great quantities of excellent pine lumber were cut in the region of White Haven and eastward. Scarcely any virgin timber remains and the second growth has yielded comparatively little lumber. The hardwoods have been cut and sawed into lumber but the entire production of local lumber is small in comparison with the quantity consumed. Manufacturers of wooden articles are varied. The furniture factories are most numerous.

Paper and Paper Products

The chief manufacturer of paper products is the Dixie Cup Co., located in the west part of Easton. Founded 20 years ago as the pioneer manufacturer of paper cups for trains, this company now produces annually nearly 2,000,000 lbs. of paper cups and containers that are distributed all over the United States and in 25 foreign countries.

The Bates Valve Bag Corporation manufactures paper bags at Nazareth for the shipment of portland cement. The Bates packer and the Bates bags, both cloth and paper, have almost revolutionized the shipping of portland cement. Now that practically all cement is shipped in bags it seems inconsistent for us to speak of the production in terms of barrels.

Newspapers and Printing Establishments

The cities and towns of the Valley have long had their local newspapers. Circulation was limited until good roads permitted the extension of their service.

The *Bethlehem Globe-Times* and the *Easton Express* hold a firm position in their respective communities and surrounding territory. Other creditable newspapers are printed in the smaller towns.

The newspapers of the region face severe competition with the metropolitan papers that reach all parts of the Valley only a few hours after their publication. Local news and local advertising however enable them to maintain themselves.

Printing establishment of various kinds are also widely distributed throughout the Valley. Most of them are local and of small capacity. The Mack Printing Co. of Easton, founded in 1907, is one of the largest concerns in the country engaged in the publication of periodicals and transactions of technical and scientific societies. It specializes in the printing of scientific books, catalogues and technical periodicals. About 40 periodicals are printed here, including Industrial and Engineering Chemistry, Electrical Engineering, Mechanical Engineering, and Civil Engineering. The company normally employs about 200 people and does an annual business of about $750,000.

Other concerns are engaged in engraving and photographic work for the printing establishments.

Leather and Leather Goods

Within a few years after the settlement of Bethlehem, leather and leather goods were being made of local hides. From that time to the present, leather manufacture has been carried on in many establishments, most of small size. Boots and shoes have been manu-

factured in larger quantities than any other products. Harness making was at one time a fairly important industry in the region but has greatly declined in recent years. Purses and various other leather articles have been manufactured.

Tobacco

Cigars are made in the towns of the Lehigh Valley. The supply of female labor and proximity to the metropolitan markets have been the determining factors in locating cigar factories in the region.

Any person acquainted with the industries of Northampton County will realize that the foregoing sketch omits scores of manufacturing establishments that produce an extremely large variety of products used locally and distributed the world over. Some of these missing may seem to certain individuals to be more worthy of mention than some included. Space limitations forbid a more complete discussion.

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